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MODERN WORKSHOP PRACTICE

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MODERN WORKSHOP PRACTICE

AS APPLIED TO

MARINE, LAND, AND LOCOMOTIVE ENGINES,
FLOATING DOCKS, DREDGING MACHINES, BRIDGES,
SHIP BUILDING, CRANES,
ETC. ETC.

By JOHN G. WINTON
ENGINEER

STRAHAN & CO., PUBLISHERS
56 LUDGATE HILL, LONDON
1870

CONTENTS.

The Marine Engine.

	PAGE
Introductory Remarks	1
Paddle Ships for River Navigation	3
The Twin Screw	4
The Marine Boiler	5
Steam-pipes	7
Feed-pipes	7
The Furnace	8
Burning the Smoke	9
The Ventilation of the Stokehole	10
Galvanic Action	10
Expansion Joints	11
Safety-valves	11
Gauges, Vacuum-valves, &c.	12
Coal-bunkers	14
Slide-valve	14
Slide-valve Facings	15
Wheel-gearing	15
Hand-gear	16
Cylinders	16
Cylinder Covers	17
Escape-valve	17
Piston-rods	18
Blow-through Cock	18
Grease-cocks	18
Condenser	19
System of Surface Condensation	20
Discharge-pipes	20
Feed-pumps	21
Hand-pump	21

920

PAGE

Main Framing 22
Connecting-rods 22
Cranked Shaft 23
Thrust-block 23
Screw Shafting 23
Screw-propeller 25

HORIZONTAL DIRECT-ACTION MARINE ENGINES.

Nominal Horse-power 30
Diameter of Cylinder 30
Stroke of Piston 32
Depth of Piston 32
Steam and Exhaust Port in Cylinder 32
Length of Ports for Double-ported Valves 33
Steam Way or Opening by Valve 33
Lap of Valve 34
Length of Valve 34
Steam-pipe on Valve-casing 35
Exhaust into Condenser 35
Relief-valve for Cylinder 35
Thickness of Cylinder 36
Double-ported Valve 36
Piston-rod 38
Slide-valve Rod 39
Air-pump, Condenser, &c. 39
Surface Condensation 44
Sea Experience with Surface Condensation 48
Boiler 51
Telescopic Funnel 57
Coal-boxes 57
High-pressure Boiler 58
Feed-pumps 58
Proportion of Water to Steam 61
Guides and Cross-head 61
Connecting-rod 63
Main Cranked Shaft 64
Cube Roots of Numbers for Shafts 65
Main Frame 66
Eccentric Strap, Rod, and Link 69
Power required to move Slide-valves 71
Hand-gear 72

PAGE

Screw-propeller 72
Griffith's Screw-propeller 74
Screw Aperture 75
Screw, Shafting, and Thrust 76
Table of Proportions of Griffith's Screw-propeller . . . 77
Piston Arrangements 79
Copper Pipes, as supplied to Ships in the Royal Navy . . 82
Flanges for Pipes 82
Bolts in Cylinder Cover 83
Hexagonal (Bolts) Nuts, Heads, &c. 83
Lubrication 84
Safety-valves 85
Expansion-valves 86
Turning-gear 87
Screw-alley Arrangement 88
Kingston Valves: Blow-off and Injection Cocks . . . 88
Rule for Tonnage (O.B.M.) 89
Proportion of Power to Tonnage 89
Maximum Speed under Steam alone 89
Performance of Screw Ships: To find the Co-efficient for Screw Ships—To find the Speed with the Co-efficient . 90
Card taken from H.M.S.S. *Icarus* 92
Weight of Machinery, &c. 93
Centre of Gravity of Machinery, &c. 93
,, ,, for 150 Horse-power 93
Cost of Labour on Marine Boilers 115
,, ,, ,, ,, per ton 116
Cost of Marine Boilers according to weight 141

Floating Docks . . . . . 94—105
Floating Docks by the Author 104

HIGH-SPEED ENGINES.

Introductory Remarks 106
Weight of Screw-propellers 108
Gross Weight of Direct-action Single-piston Engine of 400 Horse-power 109
Gross Weight of Parts of Marine Engine, 450 Horse-power . 110
Gross Weight of Cast-iron Work, 150 Horse-power Direct-acting Trunk Marine Engine 110
Gross Weight of Cast-iron Work for Two Pairs, 200 Horse-power Direct-acting Trunk Marine Engines . . . 112

DREDGING MACHINES.

PAGE

Prime Cost of Dredge Boat 114
„ „ Dredger Buckets 114
Estimate for 20 Horse-power Dredger Machinery . . 118
Contract Prices, Dredger complete 118
Double Dredger of 45 Horse-power 122
Dredger of 25 Horse-power 123
Mud Barges, dimensions of 116

Twin Screw Propulsion :—
Its Application and Uses 118
Gun-boat of 20 Horse-power 119
„ 30 Horse-power 120

Tug-boat of 50 Horse-power: Draught of Water—Oscillating Engine—Tubular Boiler—Engine Details—Paddle-wheels 121
Tug-boat of 80 Horse-power: High-pressure Engine on Diagonal Cast-iron Frame 121
Round Boilers 121
Screw Steam Ships: Dimensions and Scales of Tonnage 123, 124
Paddle Steamer: Dimensions and Scale of Tonnage . . 124

War Vessels :—
Weight and Dimensions 124
Tenders for Composite Gun-boats 125

Centre of Gravity of Vessels . . . . . 126—128

Iron Screw Steam Ship :—
Scale of Tonnage 129
Offsets (Fore Body) 130
Buttock-lines 130, 131
Offsets (After Body) 131

Displacement of River Steamer (Paddle-wheel) . . . 132
Ship Building on the Clyde (Piece Work), Prices for . 133, 138
Ship Building on the Thames (Blackwall) „ . . 134
„ „ „ (Millwall) „ . . 138
Cost of Marine Boilers according to Weight 141
„ Chain Cables and Anchors 142
„ Angle Iron for Ship Building 143
„ Machines used in Ship Building 143

PAGE

Specification of a Screw Steam Vessel of 1,767$\frac{85}{94}$ Tons . . 144
General Specification of Workmanship 145
Dimensions 146
Wood-work 148
Sundries 151

Keel, Stem and Stern Posts for all Grades 152
Frames 152
Dimensions for Angle Iron for all Grades 153
Reverse Angle Irons on Frames, Bulkheads, and Box Keelsons for all Grades 153

Thickness of Outside Plates:—
Garboard Strakes and Single Plate; Middle Line Keelsons standing up on Floors 154
From Garboard to Upper Part of Bilge and the Sheerstrakes 154
From Upper Part of Bilge to a perpendicular Height; from Under Side of Keel of Three-fifths the Internal Depth of Hold, measured from the Upper Side of Upper Deck in all Ships, whether Spar-decked or otherwise . 155
From Three-fifths the Depth of Hold (measured from the Upper Side of Upper Deck in all Ships, whether Spar-decked or otherwise) to Lower Edge of Sheerstrake . 155
Thickness of Stringer Plates upon Beams, Floor-plate Hooks, Crutches, and Box or Intercostal Keelsons, for all Grades 156
Thickness of Plates for Bulkheads for all Grades . . 156

Dimensions of Angle Iron on Beam, Stringers, or Keelsons for all Grades 157
Rudders for all Grades 157

Iron Ships:—
Prime Cost of a Paddle Steam Vessel 116
Builders' Measure *v.* Register Tonnage. By Mr. Robert Duncan . . . . . 159—169
Table of Chains and Anchors for Sailing Vessels . . . 168
„ Round Wire Ropes for Ship's Standing Rigging, &c. 169

Land Engines.

High-pressure Horizontal Land Engines 170
Crank and Eccentric Path delineated 170

PAGE

High-pressure Engines 174
Boilers 175
Chimneys 177
Pumping Engines 179
Table showing Power required to raise Water from Wells . 180
Single-acting Pumping Engine at the East London Water-works, Lea Bridge 181
Single-acting Side-lever Pumping Engine at the Duke of Buccleuch's Colliery 187
High and Low Pressure Engines at the Royal Arsenal Gun Factory, Woolwich 189
Lever Safety-valves 190
Rules for Beam Engines 191
Cold-water Pump 192
Feed-pump 192
Cast-iron Cranks 192

MISCELLANEOUS.

Teeth of Wheels 193
Table of Weight of 1 Foot of Tapered Angle Iron, Equal Sides 194
Table of Weight of 1 Foot of Tapered Angle Iron, Unequal Sides 194
Table of Weight of Square Foot of Wrought-iron Plate from $\frac{1}{32}$ to 1 Inch thick 195
Cranes 195
Relative Strength of Girders or Beams 198
Wrought-iron Beams 199
Dimensions and Cost of some Wrought-iron, &c., Railway Bridges in Scotland 200
Caisson for Docks 201
Landing Stages on the Thames (Paul's Wharf) . . . 202
Bow Lattice Girder Bridge for Raising and Lowering as the Tide flows and ebbs 202
Fixed Parallel Lattice Bridge on Piles, supported in the Middle 202
Kent Viaduct 203
Viaduct over the Thames at Staines 203
„ „ Trent 203

PAGE
Rivets for Bridges 205
Proportion of Depth to Length of Girders for Bridges . . 205
Lattice Girder Bridges 205

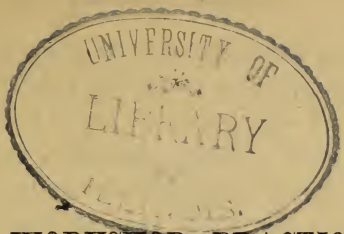
Locomotive Engines.

Introduction 210
Estimate of Cost . . . . . 222—230
Pattern Making 222
Boiler Making 222
Forging Wheels 222
Bolts and Nuts 223
Locomotive Forgings: Small Work; Mineral Wagon, &c.; Truck Wheels; Contract; Turning, &c.; Fitting; Finishing 223
Complete Specification of a Mineral Engine 225
Forgings for a Six-wheeled Locomotive Engine . . . 226
Class 230
Tractive Power 230
Weight of Goods Engine 231
Distribution of Load 231
Diameter of Cylinder and Stroke of Piston 232
Cylinder Proportions 233
Length of Steam Port and Opening by Valve . . . 233
Thickness of Cylinder 235
Diameter of Piston-rod of Steel 236
Slide Valve and Rod of Iron 236
Feed-pump 237
Motion-bars, Cross-head, &c. 237
Connecting-rod 241
Cranked Axle, &c. 243
Wheels 244
Springs 245
Horn Springs 247
Spring Harness, &c. 247
Framing 248
Boiler 250
Heating Surface and Fire-grate 253
Safety-valves 254
Furrowing and Pitting in Locomotive Boilers . . . 255
Inside Bearing and Horn-plate 259

PAGE
Axle-boxes 261
Piston 262
Outside Connecting-rods and Crank 263
Eccentrics, Rods, Link, &c. 266
Regulator 270
Motion-bar Steadiments 272
Starting-handle, Quadrant, &c. 274
General Details 277
Tender 284
Kindling Furnace and Sand-roaster 287

AGRICULTURAL ENGINEERING.

Introductory Remarks 290
Traction Engine 292
Prices of Ordinary Portable Engines 293
,, High-pressure Horizontal Engines 293
,, Boilers in the North 294
Air Furnaces in General Use 295--299
Tools 300



MODERN WORKSHOP PRACTICE.

THE MARINE ENGINE.

The study of marine engineering in all its branches is probably the most difficult the engineer has to encounter; indeed, the most experienced are often baffled with unlooked-for results. The history of the marine engine, from the side lever of gigantic proportions, with its slow but sure movements, down to the rapid revolutions of the horizontal direct-acting engines of the present day, shows one continuous course of improvement. The variety of form it has assumed, and may yet assume, is legion. The Clyde engineers may fairly claim the side lever, and direct over-head connecting-rod engines for the paddle; while to the Thames engineers we owe the oscillating and annular piston, and trunk arrangements, with other improvements. In the Clyde waters we have the inverted cylinder, for driving the screw direct, and the beam-geared engines—the former answering extremely well for the merchant

service; although for great power the plan has its objections, owing to the top weight requiring to be balanced with huge and heavy bed plates; but, on the whole, it works admirably, and takes up less room than the geared-beam engine. On the Thames we have the trunk and oscillating arrangements, both direct and indirect; as well as direct horizontal engines for the navy. This class of engine was a work of necessity, as the Board of Admiralty insisted on the machinery being placed below the water-line. That plan is now also adopted on the Continent; and properly, for in all ships the lower the weight is sunk the better, and the horizontal type, in this respect, is the best arrangement. Step by step, the marine engine of the present day has assumed all the features of its rival the locomotive. We have the cylinders side by side, with the slide-valves worked direct from the double-eccentrics and link, as first applied by the Stephensons to the locomotive; then there is the cranked shaft—indeed, without the condenser, the marine engine may be said to be a huge locomotive engine, minus the round boiler. Ere long, no doubt, round boilers and high steam pressure will be adopted for the marine engine, and even the engines materially altered—small cylinders taking the place of those huge ones now in use, and the piston speed will be greatly increased.

Paddle *versus* Screw, to some, may not be devoid of interest, but paddle and screw combined is an

abortion, although the Great Eastern has done some good service, and probably will do more, in time of war.

Paddle ships for river navigation. — Notwithstanding the regularity with which paddle ships, in all weathers, perform the journey across the Atlantic, and the rapidity with which our navigable rivers are traversed, taking into consideration the many rivers of India, that are almost without the means of transporting the produce of that vast region, we must still look for further improvements; for undoubtedly the paddle possesses many advantages over the screw-propeller, for the river navigation of ships of light draught. As yet we have had but little experience of such craft. They must necessarily be formed of light scantling, and trussed with lattice beams, running fore and aft. In some instances the deck has been formed, or rather the awning, of plates of iron or steel, so as to form the top web of a girder, the bottom web being the skin of the vessel itself. This is rather an ingenious plan, but such an arrangement would likewise require an ordinary sail cloth awning, as the powerful rays of the sun would make the overhead plates intolerably hot. As river water is comparatively pure, the high-pressure steam engine is used, with the ordinary locomotive boiler; this is found necessary in order to reduce the weight, as likewise to distribute the weight over a large surface. The engines, of the diagonal type, the framing being

formed of wrought-iron plates, strongly fixed to the vessel—in fact, forming part of the structure—and cylinders of 18 inches in diameter, with a stroke of 5 feet, and long trussed connecting-rods, spread the weight over a large surface; the steam pressure of 100 lbs. per square inch, with a powerful steam blast; the exhaust from the cylinders blowing up the chimneys tends to reduce the size of boiler, and, consequently, the weight. The paddle wheels are of the ordinary construction, fitted with teeth cut round the outside rings, with a pinion, driven by an auxiliary engine, so as to assist the vessel over any obstructions of sand or mud. The vessel is formed of a spoon shape at the bow, so that the water may freely flow under, thus washing away mud or sand that may obstruct its path.

The twin-screw method of propulsion, as applied for light draughts, has proved a great success; indeed, it has now gained great favour for ships of war; the screws and engines being independent of each other, a vessel can be steered or manœuvred independently of the rudder, and when both are brought to bear the vessel can be turned almost in its own length. There were many objections to the twin arrangement; complication of the parts, and the want of a good design of engine, seemed the greatest difficulties to encounter; but those objections have been removed. Twin-screw engines can be placed in less space than single screws of the

usual type: the condenser and framing being in one casting, placed on the centre line of the vessel, and the cylinders lying diagonally, forming a very compact arrangement; and when high speed small pistons are adopted, with pinion on engine shaft, and spur wheel on the propeller shaft, they can be made for as great a power as is now applied in the Royal Navy, and all the machinery be placed below the water-line. For the merchant service the advantages of this arrangement are great, as a ship can carry more cargo or coals; the weight of machinery for high speed being represented by hundredweights instead of tons as in the low-speed engine.

The marine boiler.—The improvements in marine boilers have not been so great as in marine engines, though the multitubular was a decided advance upon the old flue boiler. So long as 20 lbs. to 30 lbs. steam pressure is used, probably the large flat-sided boiler will still be adopted; but when we consider the locomotive boiler of small size giving out 1,000 horse-power, it is very evident that the round marine boiler should be more extensively used. It is the strongest form, and with a judicious arrangement of furnaces, combustion chambers, and small tubes over-head, a quick steam-producing boiler can be made; the flame and heated gases first acting on the furnace surfaces, then dipping into a bottom combustion chamber, carrying the flame to the front of boiler, through which it ascends into a second combustion chamber,

and then through the small tubes; thus the flame acts over a larger flat surface, and the dead water under furnace is better circulated. To keep all the particles of water in ebullition is the most natural way of getting the greatest economical result; and this is done by the small locomotive boiler, with all the water space honeycombed, as it were, with hundreds of square feet of heating surface, occupying not more than one quarter the space of an ordinary marine boiler. In using salt water, deposits form over the furnace heating-surface, and soon impair the conductive power of the metal. To obviate this there is a very simple method adopted by some of our first class sea-going engineers, the boilers are, in the first instance, filled with salt water, and run with such until a very thin film of deposit is formed all over the surface exposed to the flame; and then the water from the surface condenser being turned on, the rapid incrustation that otherwise would go on is prevented. To prevent radiation, the boilers are in some parts covered with felt or wood, and then a covering of sheet lead over all. The bottoms of the boiler should be left open as much as possible, sufficiently high above the bilges, so as to get at them for slight repairs, or an occasional inspection and painting. The inside of the boiler should have a coating of red-lead, and the bilge-water should always be pumped out by the bilge-pumps; in fact, the inside of any ship should always be kept as dry

as possible. Sometimes the boiler is laid on a bed of mastic, but the former plan of leaving a wide space is decidedly the best under all circumstances.

Steam pipes.—The copper steam pipes are carefully clothed with felt and canvas, so as to keep the steam as dry as possible; indeed, the steam is sometimes cooked, as it were, before entering the cylinders; but this plan of superheating the steam has its disadvantages, it being expensive to keep up—the superheater being simply a dry boiler placed in the smoke-box, so that the heated gases, after doing duty in the boiler, are made to roast or dry the steam. But the apparatus soon gets used up, and even the dry steam hardens the lubricant in the cylinders, and thus the valve, faces, &c., are rapidly worn out. All the steam pipes—indeed all pipes, whether for feed, injection, &c.—should be as straight as possible, and all the bends of a large radius, more especially the delivery pipes from the condenser, as right-angle elbows form a great resistance to the water, which is delivered in some instances at 450 feet per minute, the usual speed for pumping engines being only 160 feet per minute.

Feed-pipes.—The feed-pipes for fresh water should be fitted to, or injected into, the boiler as low down as possible; indeed, I think we have long erred in placing the check valves immediately over the furnaces. In land and locomotive boilers, the feed-

water is placed as far as possible from the fire-box, or furnaces; the parts where the steam is more rapidly raised should always be kept as hot as possible, which cannot be the case when a body of cold water is injected over the surface. Heat has a natural tendency to ascend, and when the feed is taken in at the bottom of the boiler, it is partially heated before coming in contact with the top of the furnaces, and will thus materially assist in raising steam at a more rapid rate, and will likewise effect a saving in fuel.

The furnace.—The firemen's duty on board ship is very arduous. When we take the consumption of coal at 2½ lbs. per indicated horse-power, and the indicated power at 1,000 horse-power, we have 26 tons of fuel for a 24 hours' run. The coals should be carefully broken up in pieces about 1 lb. weight, and a good fireman will always keep a well-spread furnace bar—not considering it his duty to shovel on the greatest quantity per day, or by heavy charges at one time, but by a succession of a few shovelfuls oft-times repeated. In tropical climes the firemen's duty is very severe, consequently the number employed must be more than for a more northern hemisphere. A mode of mechanical firing would be a step in the right direction, but probably the complication entailed would make it troublesome to keep in repair. Clearing the fire from clinkers, with the furnace door wide open, is very warm work. A smaller hole in the

furnace front, with hinge plate, similar to working the rabble in the puddling furnace, might tend to lessen the labour, and likewise prevent, in a measure, such a rush of cold air passing through the boiler when the door is full open as in the present method. As the bottom of the furnace rapidly wears, and the rivet-heads get rubbed away by the mere friction of the tools for raking out the ashes, a false bottom may be fitted, or otherwise a smooth loose plate, so that the ashes would never come in contact with the boiler plates; and no water should be used to quench the ashes in the bottom of furnace, but they should be withdrawn on the stoke-hole plates, and a jet of water, carefully extinguishing them, will prevent a cloud of dust and vapour arising, and likewise preserve the bottom of the furnaces from rust, that would otherwise form if the water were dashed into the ash-pit. Indeed, some boilers have no bottoms to furnaces, but simply a dry plate fitted; and as most ships—I may say all—are now built of iron or steel, such a plan is not so dangerous as in the old "wooden walls."

Burning the smoke.—A method of burning the smoke has not fully met the consideration it deserves. Jets of steam have sometimes been adopted blown in from the front of furnaces, but this plan is wasteful. A very good plan has been successfully used for Cornish boilers, by simply introducing small tubes, from the front of the boiler, passing through the

water space. Thus, a current of heated air is conveyed to the combustion chamber, or where the flame from the two furnaces meet, effectually burning the smoke. Such a plan can be easily introduced in the round boilers already referred to, the heated air meeting the flame as it descends into the bottom combustion chamber; thus both combustion chambers would be filled with pure flame, and the smoke utilised in a beneficial manner.

The ventilation of the stokehole is of the highest importance. Many bad arrangements of boilers having the steam chests meeting over-head, allow of no circulation fore and aft, and consequently necessitate the adoption of an artificial ventilation, by the use of a fan driven by an auxiliary engine. It is more preferable to project the boilers a little in front of the furnaces, having the uptakes or smoke pipes on the top of the boilers, and connecting them with a dry uptake, having a free passage, considerably above the boilers, so that the air can freely circulate. The chimney is surrounded with suitable air-casings, having holes all round at the bottom, by which the vitiated atmosphere is rapidly taken away, and fresh air conveyed downwards from the deck by suitable air-funnels, generally made of canvas, having an oblong open mouthpiece at top, that can be turned against the wind; and as these funnels are light, they can easily be removed when in port.

Galvanic action.—As galvanic action rapidly sets

in where brass and iron are jointed together, it is necessary to fit cast-iron boxes, or short pipes, to the skin of an iron ship, for the Kingston and other arrangements for the entrance and exit of the water. Cast iron after long exposure to salt water turns quite rotten, or assumes the consistency of plumbago; therefore all the cast-iron branch pipes should be galvanised, so as to protect them—more especially for the Kingston valves, as they are placed in situations not easily reached; and, should accidents occur by the breaking of the cast iron, these valves could not be reached at all, as they would soon be submerged.

Expansion joints.—Wherever there are complicated arrangements of piping, all the parts exposed to severe strain should be fitted with suitable expansion joints; but in the case of pipes under steam pressure, care should be taken that no expansion is fitted on bends without having proper means of securing the pipe in the expansion joint with a suitable collar at the end of pipe; as fatal accidents have occurred from the steam, by its reaction force, blowing out the bend—bends under pressure, whether of steam or water, having always a natural tendency to assume a straight form.

Safety-valves.—Although the safety-valves are so constructed that they cannot be tampered with, it is the practice to fit an additional safety-valve, under lock and key—the commander of the vessel keeping the key. This is found necessary, so that the boiler

can never be strained above its working pressure. Boilers after a few years' use are not calculated to sustain so great pressure as when new, and the load on the safety-valve should be reduced to the extent the Government inspector may determine. This is more requisite with surface condensation, as the boilers, under inexperienced hands, rapidly deteriorate. As an additional precaution, a mercurial gauge is fitted, which simply consists of a bent tube with a cock at top, and the other end open, the tube being partially filled with mercury. As glass tubes are liable to be broken, the tube is sometimes of wrought iron, fitted with a float and plumb-bob, with a graduated scale alongside, the steam acting on the top of the mercury. Each inch of mercury on the scale indicates about 1 lb. pressure, and as the mercury is depressed 1 inch on one side, it is raised 1 inch on the other, making 2 inches height of mercury—equal to 1 lb. steam pressure. Should the safety-valve get fixed, and the pressure in the boiler get above the working pressure, the mercury is blown out of the gauge, thus giving warning to an attentive man, who will at once open the furnace doors; but should the mechanical gauge show the steam at a dangerous pressure, the engineer must at once withdraw the fires.

Gauges, vacuum-valves, &c.—To ascertain the proper level of water in the boiler, the usual glass gauge is fitted to a cast-iron pipe projecting from

the front of the boiler, extending from the steam space to about the crown of the furnace. As sometimes the small cocks on the gauge get choked, additional test cocks are fitted to the side of the cast-iron pipe, so that the engineer can at once tell by simply opening them whether there is sufficient water in the boiler. As the pressure in the boiler may, at times, fall below the pressure of the atmosphere, or a partial vacuum be formed, a reverse valve is fitted—simply a spindle valve, with brass valve chest, the steam pressure acting on the top, and open to the atmosphere at the bottom, so that air rushes in and destroys the vacuum, thus preventing the boiler collapsing. The stop-valves are fitted with a screwed spindle and handle, the steam pressure tending to open the valve. Stop-valves should never be opened or closed too suddenly, as the reactive force of the steam, when the valve is shut instantly, tends to strain the boiler. The usual scum-cock is fitted to the boiler at about the water-line, having a copper pipe attached for blowing overboard, and an internal pipe, with a trumpet mouthpiece, for collecting the scum. The blow-off cock is fitted to the bottom of the boiler, between the furnaces, having a Kingston valve at the bottom of the ship. The check-valve is fitted to the end of the feed-pipe on the boiler, so that when the feed is not on, the pipes are not strained, and in case of accident the steam or hot water does not escape into the engine room.

Coal bunkers.—As all coals are liable to heat from spontaneous combustion, the coal boxes or bunkers should be fitted with temperature tubes, so as to be able to ascertain the temperature at any time; and as most coal evolves highly explosive gases, the bunkers must be properly ventilated, so that the gases evolved can escape into the atmosphere. It is a good practice to line the bottoms of bunkers with wood, or have them plastered over with Roman cement, so as to prevent corrosion setting in. Roman or Portland cement is largely used also for coating the inside of iron ships, so as to prevent the bilge-water wearing off the rivet-heads, and for protecting the hull from rust.

Having thus considered the chief points to be attended to in the stoke or boiler room, we have now to turn our attention to the engine room, and see what must be studied in designing marine engines so as to attain a good result.

The slide-valve of the marine engine is the most important detail. Considering the great size that is now required for the direct-acting engine, it should be of the best proportion for the requirements, and all the valve gear of a strong and substantial make. It is generally worked direct from double eccentric and link motion, and in the marine engine this motion is simply introduced as a sure means of handling the engine. The link is always in full gear, and very rarely used in any other grade, for

expansion or cutting off the steam, at various parts of the stroke, as in the locomotive engine. It has often been remarked, "Why not use the link for working expansively, as in the locomotive?" The answer is simple: were it the practice to do so, as the marine engine may run for weeks in the same grade of expansion, the valve face or cylinder face would be worn unevenly, when a groove would be formed; and when the valve is in full travel, the steam would find its way into the condenser, thus impairing the vacuum. It is, therefore, imperative to have a separate valve for working expansively.

The slide-valve facings, in days gone by, were made of brass, pinned on by screw studs, and then riveted; but this is not required, as the valve is generally on edge, or lying at a slope, so that any water collecting finds its way to the bottom of the valve casing, and is run off by a small cock fitted to the latter; thus the valve is kept dry when in port, preventing corrosion that would otherwise set in.

Wheel-gearing for working the valve, with a judicious arrangement of valve, so that the steam pressure on the back of valve is greatly reduced, will probably soon find favour. Simplicity on board ship is the main thing to be considered, and although some have a prejudice against gearing, it is unquestionably the simplest motion extant, and properly proportioned gearing has less friction, and is more

economical in lubricants than the double eccentrics and link motion.

The hand gear should be arranged on the same platform or level as the stokehole. However, some place the starting gear on the top of the condenser, and certainly the engineer has a better view of the machinery in that position; but his duties, under steam, are between the engine and stoking rooms; and the hand gear should be so placed that at a moment's notice he can reach it; and the various handles so arranged that he need not move from the starting handle. We have seen hand gear sprawling all over the engine room; indeed, have had to come down from the top of the condenser and open the cocks, on cylinders, so as to allow water to escape, when the boilers were priming or boiling over by using, or changing dirty water in going up rivers, when, by a simple arrangement of rods and levers, this could have been done from the starting platform.

The cylinders in the direct-acting horizontal engine are placed side by side, the distance between the centres being regulated by the arrangement of air-pumps and head and foot valves. When the air-pumps are close together on each side of the middle frame, the distance between the centres of the cylinders is greater than when the air-pumps are arranged farther apart, and close to the outer frame; but in no case should the water passages in condenser be contracted so as to gain a few inches between cylinders. It is the

practice of a few to steam-jacket the cylinders, while others are contented to cover them with felt and wood, so as to prevent radiation or condensation in the cylinder. The condensation in the outer shell is not of so much consequence, but certainly where such is fitted it should be lagged or felted, and wood over all, to make it complete. All the joints in good engines are simply metallic, all planed, and when such a removable and steam-tight. As for the slide-valve and cylinder face, the surfaces are scraped, and made thus perfectly steam-tight. This is a nice piece of work, and requires much care. All the other steam-tight joints get simply a coating of red lead, about the consistency of thick paint, before they are screwed together, and as there are thus no elastic joints, the whole mass may be considered solid. Some engineers have cast large cylinders together, which certainly tends to cheapen the manufacture; but the danger of having bad castings must deter many from following such a plan, although there is not much risk with moderately-sized cylinders.

The cylinder covers should be deep, and well ribbed, so as to prevent the pulsations so painfully seen in shallow covers by the rapid admission and exit of the steam. They are fitted with a small man-hole cover, so as to be easily taken off for inspecting and tightening up the piston-rod bolts, &c.

Escape-valve.—On both ends of the cylinder an escape-valve is fitted, so as to allow water that may

collect from condensation and priming of the boilers to escape into the bilge. The valve is simply a spindle one, with spring on the top to resist the internal steam pressure; and, as water is not compressible, it is ejected by the piston until the inside of the cylinder is quite free. An additional cock is fitted so that the cylinder can be entirely drained, as the escape only comes into action when violent priming goes on.

The piston-rods have the usual stuffing-boxes, and an additional one placed on the gland flange, fitted with a lattern or hollow distance piece, so that the lubricant is poured into the space instead of on the rod itself—thus the rod is always surrounded with a flow of oil, and no waste can occur. The front end, of course, has the usual small hole and cover, so that the boring bar for boring out the cylinder passes through; it may likewise be taken off occasionally for inspection.

The blow-through cock is fitted to branches on the steam-pipes, on cylinder, and pipe to condenser. It is sometimes a plain spindle-valve, the steam-pressure acting on the top. It is opened with a little lever on the valve-box, with a rod and handle passing along to the starting platform.

Grease cocks are fitted to the front and back steam-ports, so as to lubricate the piston with tallow, drawn in with the vacuum. These cocks are fitted with a screw-thread at top, so as to fit

the indicator; and a pipe is connected between the cocks, so that an indicated card can be taken from the front and back without shifting the instrument. An additional cock must be fitted on this pipe, so as to shut off the communication from the front to back.

The condenser should be as plain and simple a casting as possible; water, on no account, should be tortured through intricate passages. Where large flat surfaces are, they should be strongly ribbed in the casting itself. Sometimes wrought-iron stays are placed inside to strengthen the sides. The exhaust-pipe on the condenser is fitted with an expansion joint, the end of the pipe passing through a loose hoop inserted at the bottom of the stuffing-box. This is necessary, so as to be able to disengage the pipe without disturbing the cylinder or condenser: the hoop being withdrawn, sufficient play is given for the pipe to be skewed out of its place. The snifter, or the valve, for blowing all the air, water, &c., out of the condenser, should be placed as low as possible, the valve should simply open upwards, and be fitted with a baffle-cover, so as to throw the ejected water down into the bilges. The escape-valves on the cylinder are likewise so fitted as to prevent the engineers being scalded with the water ejected from cylinders. The snifting-valve is likewise fitted with a screw for holding it down when not required.

The system of surface condensation is introduced to obtain a supply of fresh water for the boilers, the boilers with the great amount of tube surface in the first place raising the steam; and a similar arrangement of tube surface surrounded by cold water, or otherwise the sea water drawn in and circulating through the tubes condenses the steam, the water being again forced into the boilers in the usual way. When we consider the great speed with which the sea water is forced through the tubes, or made to circulate around them, it is highly necessary that the tubes should be made of sufficient strength to resist the strain. We shall treat this part more fully when dealing with details, giving the proportion usually adopted. Some may imagine when the boilers are once filled with pure water, that by this method of condensation and using the steam over again, as it were, no more water would ever be required. This, however, cannot be the case, as it is necessary in the system to blow-off occasionally, and steam also escapes by the safety-valves.

Discharge-pipes, fitted to condensers, should be arranged with an expansion joint on the discharge-valve box at the ship's side; and as the valve box generally passes through the coal boxes, a mode of lifting the valve from the orlop-deck must be provided. The injection-valve, fitted both to plain and surface condensers, is simply a sluice valve, with pipe and Kingston at the ship's side, placed as high

up on the condenser as possible, and fitted with an interval pipe perforated with long slits. It is so situated that it meets the educted steam in the most effectual manner. The bilge injection-valves are only used in the event of great leakage in the ship. They are simply spindle valves, with stuffing-box and handle, fitted with a pipe and rose, so that any foreign matter, such as small coal and waste, or cotton wipings, &c., cannot find its way into the condenser. This valve is placed as low down on the condenser as convenient.

The feed-pumps sometimes form part of the condenser casting, but the usual plan is to make them in separate castings. They are generally of the single-acting plunger type, having means of disconnecting the plunger when in motion. The bilge-pumps are of the same pattern, and both are worked direct from the end of the piston-rod, or have arms arranged so as to work them above the piston-rod, as in the return connecting-rod type.

The hand-pump is an additional pump, generally worked off a pin on the end of the cranked shaft. It is arranged so as to be worked with a lever, and must likewise have the means of disengaging it and setting it in motion without stopping the engine. Its duty is somewhat complicated. The pipes from it must be so arranged as to draw water from the boiler, from the bilge, and from the sea—as likewise to discharge the water into the boilers,

on deck, and overboard. It is fitted with an escape-valve, loaded with a solid block of lead.

The main framing should be a strong section, and as open as possible, so as to get at the glands, &c. It should be well secured to the cylinder condenser and keelsons. When the distance between cylinders is great, the centre bearings can be increased in length, so that no undue strain is transmitted to the cranked shaft. In fact, the shaft should always be supported as close to the cranks as possible.

It is the general practice to scoop out part of the brass bearings, and fill the spaces with white metal—to prevent the bearings heating—but the best preventive is good workmanship.

Connecting-rods.—There are a variety of forms in connecting-rods, the most approved mode of construction being to form the ends solid, turning or slotting out the parts for taking the brasses, and having the caps secured with bolts and nuts. In some cases the rod is hollowed out or bored up the centre, so as to fit a small steel rod, with jibs and cutters, in order to tighten up the brasses. In all trunks for cylinders, or air-pumps, this is a good arrangement. The cross-head and motion bars for direct-acting horizontal arrangement, on the return principle, are double: at least, this is the best plan; as the motion bars are on the centre line, and the cross-head is simply a round bar, with arms forged at the ends for taking the piston-rods.

The cranked shaft is forged in one piece, having two crank-pin bearings. However, should it be required, when the distance between crank-pins is great, the shaft can be made in two pieces, and fitted with discs forged on the shaft at centre of engine. This plan requires two centre bearings. The screw shafting is made in convenient lengths, and coupled together with solid discs forged on the shaft, and secured with bolts and nuts; as the bolts have comparatively small area compared with the shaft, a cutter is inserted, taking each disc, and thus the sheering strain is taken off the bolts.

The thrust block, as it is termed, is an ordinary pillow block, fitted with a series of gun-metal collars, having corresponding collars on screw shafting, so as to take the forward movement imparted to the shafting by the action of the screw-propeller. As this thrust or push is in the direction of the path of vessel, the collars are so arranged as to suit the *go-a-head* and *astern* movement.

The screw shafting is supported with common pillow blocks of cast iron, lined with white metal, and at the extreme end or stern a long cast-iron tube is fitted with flange for screwing up the tapered part that passes through the stern-post, so as to make it perfectly tight. The length of this tube is determined by the fineness of the run of vessel, a fine run requiring a longer tube than a full one, so as to give ample space for the inside stuffing-box

and gland. On the extreme end of the screw shaft a brass tube is shrunk on, which works into a brass bearing inside the cast-iron tube, this bearing being lined with wood, for which purpose *lignum vitæ* is the best kind. This simple plan is due to John Penn, Esq., M.E., of Greenwich, and has been the chief cause of the great success of the screw-propeller. Without such an appliance, steam vessels would require constant docking, as with the old brass bearings, the action of the screw soon knocked the bearing out of truth, causing a violent thumping action, or a repetition of blows, that played havoc with the after-part of the ship. We do not know how long the wood bearings remain true, but we know that the bearings of the *Royal Charter* never turned a hair, the vessel having accomplished a distance of 188,000 miles, and there is not the slightest doubt she would have gone over the same space without having to be renewed: in fact, the marks of the boring-out tool were plainly perceptible, thus showing that the wear was very slight indeed. Of course, this bearing requires a plentiful supply of water, as the lubricant. Lubrication, in all the parts of the machinery, is of the highest importance; and all rattle-traps should be avoided, such as oscillating pipes attached to the reciprocating parts of the machine, such contrivances not being calculated to withstand the wear-and-tear of fast-going engines. The appliance should be plain and efficient; the

oil and water lubrication should be separate—the latter providing a plentiful supply of water in case of heating in the bearings, as such at times will occur in the best examples. It is absolutely necessary when a vessel is in port that the machinery should be daily turned round by hand, as the brass lining in the stuffing-boxes, &c., being in contact with the iron piston-rods, would form grooves or ruts, through the oxidation of the two metals, by the galvanic action that sets in when brass and iron are in juxtaposition.

We have now considered the leading features to be attended to in the manufacture of the marine engine; but many points have been passed over that can only be acquired by practical study.

The screw-propeller.—We have often been asked to give an explanation of the action of the screw-propeller. It is unnecessary to state that the action is endless—an endless screw propelled by a steam engine on board ship. Although the screw revolves in a contrary direction, or rather a cross direction to that of the ship itself, it still forms part and parcel of the structure. The boss of the screw (as in an ordinary screwed bolt) forms the bottom of the thread, and the blade of screw forms the thread. The thread of a screw can be delineated by simply rolling a piece of paper round a circular piece of wood, the paper being cut in the form of a right-angled triangle. The base is the circumference, the perpendicular is the pitch, and the hypothenuse is

the line that will delineate the thread, when wound round the block of wood. Thus, a point on the thread, when moving in a nut having a corresponding thread, will move forward the extent of the pitch in a single revolution. In this way we have the screw-propeller, as an endless screw, working into an endless nut, "the ocean;" the pitch, we will say, is 20 feet, and suppose the distance the vessel has to travel over is 4,000 feet, the screw would require to make 200 revolutions so as to move the vessel that distance. The action of the corkscrew, when inserted into a corked bottle, is similar to the action of the screw-propeller. With each revolution caused by inserting the screw into the cork, a certain progressive movement is made due to the pitch or spiral; but as the screw-propeller moves in a yielding fluid, sometimes the screw slips, or as it were, the thread of the nut is broken for a time, and the screw revolves without imparting any forward motion to the vessel. This is termed the slip of the screw, which is about 10 to 20 per cent. Again, we have what is termed negative slips, the screw moving through less space (even although working, as in a solid nut) than the speed of the vessel—the vessel, as it were, outstripping the screw, or otherwise dragging it through the water. This, however, has become a rare occurrence now-a-days, and can be wholly attributed to the full after-lines, as with a clean run aft this does not occur.

It is a difficult matter to say what is the best pitch for any given vessel, as the lines of the ship seem the only guide to go by. How necessary, therefore, is it that engineers and shipbuilders should work hand in hand. When a manufacturer of steam engines contracts for engines to be put into a vessel by another firm or shipbuilder, he should always be provided with the lines of the ship, so as to compare results. Some screw-propellers are made to feather, so as to be able to arrive at the best pitch. This, to a certain extent, is advisable, but when carried too far, the blade of the screw assumes nothing else than an oblique board. Still, if we are able to get one half-knot more speed out of the vessel, with this deviation from a truly scientifically constructed screw, so as to suit the known run of the ship as found, surely it is more preferable to arrive, in the first instance, at the pitch to be adopted, which can only be done by studying the lines of the ship, and comparing them with former practice. Thus when we arrive at a good result, with the best form of vessel, we could further improve on it, and should it be desirable to increase the speed of the ship we could do so, bearing in mind that the power required varies as the cube of the speed.

For instance, let us take a vessel of a certain form and tonnage, with a speed of 12 knots an hour. Should it be desired to make another vessel of the same lines attain a speed of 15 knots per hour, we should have

the following calculation. The horse-power in the former being 400 : the cube of 12 is 1,728, and that of 15 being 3,375, thus—

$$\frac{3{,}375 \times 400}{1{,}728} = 781 \text{ horse-power,}$$

or very nearly double the power, to gain an additional speed of 3 knots per hour. Now this becomes a serious consideration, as the amount of coal consumed is in the same ratio. We will take an example : supposing the distance the vessel had to steam over was 1,500 knots, going at 12 knots per hour, it would require 125 hours to accomplish the distance; going at 15 knots, it would require 100 hours; and taking the horse-power as indicated, and the coal consumed, per horse-power, at $2\frac{1}{2}$ lbs., we have

$$400 \times 2{\cdot}5 \times 125 = 125{,}000 \text{ coal in lbs.}$$
$$781 \times 2{\cdot}5 \times 100 = 195{,}250 \quad \text{,,}$$

Thus we have then about 31 tons, in round numbers, extra coals to carry to perform the same journey, but it must be borne in mind that the distance is run over in 25 hours less time. Thus, it will be seen, that high speed is best suited for moderately short trips, and best adapted for the merchant service, where despatch is required. Of course, all steam vessels should be constructed to meet their requirements.

Theoretically and practically it has been proved, under all circumstances, that a low rate of speed, in an economical point of view, is the most ad-

vantageous. Thus, when vessels—ships of war, we will say—are in no hurry to perform a certain distance with a given quantity of coal, it is advisable to work the engines at half-power, or only use the half of the boiler-power, or a fractional part of the power, as may be thought best under the circumstances. The nominal horse-power of a steam engine has nothing whatever to do with indicated or actual power developed; and, although we may calculate the theoretical power to a nicety, the real power of the engine can only be obtained by taking a card off the engine, by means of the indicator. We will now proceed to draw attention to the proportion to be adopted in manufacturing the marine engine, and in doing so we may state that the proportions given are a mean between what is extremely light, and that where a superabundance of material is used.

HORIZONTAL DIRECT-ACTION MARINE ENGINES.

NOMINAL HORSE-POWER.

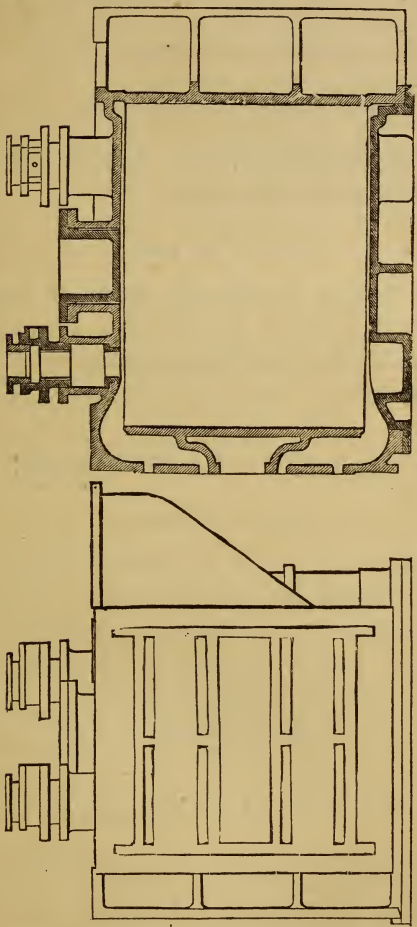
For calculating marine engines, or in buying and selling, a commercial unit is used, denominated nominal horse-power, or, in other words, a certain number of square inches of cylinder area and velocity of piston in feet per minute is given; 7 lbs. per square inch being the recognised pressure, and 33,000 lbs. the duty of one horse-power per foot in a minute, hence the following formula—

$$\frac{\text{area of cylinder sq. ins.} \times 7 \text{ lbs.} \times \text{ft. per minute}}{33{,}000} = \text{H.P.}$$

DIAMETER OF CYLINDER.

As the diameter of cylinder must be determined by the speed of piston, and as most manufacturers fix their own speed of piston, which averages from 240 ft. per minute for 50 horse-power collectively having a 16-inch stroke, to 300 feet per minute for 400 horse-power collectively, having a 36-inch stroke, so, for example, I will assume the latter power and speed in my calculations. To find the number of square inches per horse-power, divide 33,000 by the product of the speed multiplied by

7 lbs., and the result gives the square inches per horse-



power; then multiply this by one-half of the power

required, to which add half of the area of piston-rod —or by multiplying the horse-power by ·14—and the product gives the area of each cylinder

$\frac{33,000}{300 \times 7} = 15{\cdot}714$ square inches $\times$ 200 horse-power = 3,142 square inches + 28 = 3,170 area of cylinder = $63\frac{1}{2}$ inches diameter nearly.

STROKE OF PISTON.

Some relation between the stroke of piston and diameter of cylinder is necessary. A good result will be obtained by dividing the diameter of cylinder by 1·76, giving even numbers always the preference—

$$63{\cdot}5 \div 1{\cdot}76 = \text{say 36-inch stroke.}$$

DEPTH OF PISTON.

The depth of piston is usually one-fifth of the diameter of cylinder, to which add the length of stroke, making an allowance for clearance at ends of $\frac{1}{2}$-inch for 25-inch cylinders, to $\frac{3}{4}$-inch for 63-inch cylinders, and the product is the length of cylinder inside; that is, from the inside of front end to the inside of cover—

$$12\frac{1}{2} + 36 + 1\frac{1}{2} = 50 \text{ inches long.}$$

STEAM AND EXHAUST PORT IN CYLINDER.

To obtain a free steam and exhaust, the ports in cylinder are greatly in excess of valve opening—

one-nineteenth of cylinder area for steam, and one-eighth for exhaust—

3,170 ÷ 19 = 166 square inches for steam-port.

3,170 ÷ 8 = 396 square inches for exhaust-port.

N.B.—The exhaust is ruled by the distance of face from cylinders, as the exhaust into condenser is greatly throttled at the side of port, so to obviate this the exhaust-port is made broad in the direction of the travel of valve.

LENGTH OF PORTS FOR DOUBLE-PORTED VALVES.

The steam-ports in cylinder are divided by a centre rib 1½ inch broad, while that of the exhaust is left free. The combined length of steam ports is found by dividing the diameter of cylinder by 1·7 and 63·5 ÷ 1·7 = 37·3 inches, a little either more or less, to insure even dimension: say 38 inches, or four ports on face 19 inches long and 2¼ broad at each end, and for exhaust 38 + 1·5 = 39·5 inches long, 396 ÷ 39·5 equal 10 inches broad nearly.

STEAM WAY OR OPENING BY VALVE.

The full opening by valve at each end is obtained by multiplying the cylinder area in square inches by the speed of piston in feet per minute, dividing the product by the constant 10,000.

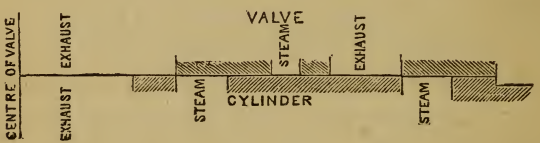
$$\frac{3{,}170 \times 300}{10{,}000} = 95 \text{ square inches} \div 38 = 2{\cdot}5 \text{ inches.}$$

This result, divided by 2 for double-ported valves,

gives four openings at each end, 19 inches long and $1\frac{1}{4}$ inch broad. This width is the most important dimension of the steam engine; it regulates the amount of supply, and consequently the number of revolutions; and from it the correct lap of valve is obtained for cutting off the steam at any part of the stroke that may be determined on.

LAP OF VALVE.

In my own practice I have a convenient instrument for finding the correct lap, which I will explain hereafter; in this instance it will be $1\frac{7}{8}$-inches, cutting off at about five-eighths of the stroke.



LENGTH OF VALVE.

It will be seen from the diagram that all the ports are closed, or otherwise the valve at half-stroke. To get the correct length of valve facing, I will commence on the cylinder side; one half of exhaust in the condenser equals 5 inches, metal surface $1\frac{3}{4}$ inches, steam-ports $2\frac{1}{4}$ inches, large metal surface $7\frac{1}{2}$ inches, steam-port $2\frac{1}{4}$ inches, metal surface $1\frac{7}{8}$ inch. Thus we have

$$5 + 1\frac{3}{4} + 2\frac{1}{4} + 7\frac{1}{2} + 2\frac{1}{4} + 1\frac{7}{8} = 20\frac{5}{8};$$

this, multiplied by 2, gives $41\frac{1}{4}$ inches length on cylinder. It will be seen that there is only one steam-port at each end of the valve for admitting the steam into the cylinder, and one exhaust-port at each end, and one large central one, the half-breadth being $6\frac{3}{4}$ inches, the metal face $4\frac{1}{8}$ inches, steam-port $1\frac{1}{4}$ inch, metal face $1\frac{1}{4}$ inch, exhaust-port $3\frac{1}{8}$ inches, $4\frac{1}{8}$ inches. Thus we have

$$6\tfrac{3}{4} + 4\tfrac{1}{8} + 1\tfrac{1}{4} + 1\tfrac{1}{4} + 3\tfrac{1}{8} + 4\tfrac{1}{8} = 20\tfrac{5}{8},$$

multiplied by 2, equals $41\frac{1}{4}$ inches.

STEAM PIPE ON VALVE CASING.

The steam-pipe branch on valve casing is one-twentieth of the area of cylinder, and the main steam-pipe two-thirds of the two combined:—

$\frac{3{,}170}{20} = 158{\cdot}5$ square ins., $14\frac{1}{8}$ ins. diameter nearly, for branch pipe, and for main pipe $158{\cdot}5 + 158{\cdot}5 = 317$, two-thirds of which $= 211 = 16\frac{1}{2}$ inches diameter nearly.

EXHAUST INTO CONDENSER.

The exhaust into condenser is one-twelfth of cylinder area $3{,}170 \div 12 = 264$, or $18\frac{3}{8}$ inches diameter.

RELIEF VALVE FOR CYLINDER.

The cylinder relief valves are found by dividing the cylinder diameter by twelve, equals $5\frac{1}{4}$ inches; smaller cocks are sometimes fitted on the same valve

chest, worked by levers and handles from the starting-platform.

THICKNESS OF CYLINDER.

From practice I find the thickness of body of a 25-inch cylinder is $\frac{7}{8}$ inch; for every 5 inches extra diameter add $\frac{1}{16}$ inch :—

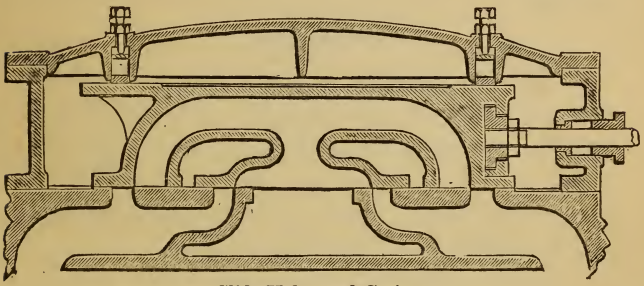
$$\frac{63-25}{5} = 7{\cdot}6, \text{ say } \tfrac{1}{2} \text{ inch}; \quad \tfrac{1}{2} + \tfrac{7}{8} = 1\tfrac{3}{8} \text{ inch.}$$

The flanges for covers should be one-fourth more than the body; ends and covers one-tenth more than body. The ends and covers have strong ribs radiating from centre; depth of covers, including ribs, one-eighth of cylinder diameter. The body of cylinder is cast with two deep rings for strength, and for securing the lagging, or wood, covering the felt to prevent radiation. In large cylinders the covers have a man-hole door. The thickness of the sides of the steam-chest is $\frac{3}{4}$-inch for cylinders 25 inches diameter, to $1\frac{1}{4}$-inch for cylinders $63\frac{1}{2}$ inches diameter. The steam-ports are divided by a centre rib, but the exhaust is left free, and is carried round cylinder by a broad belt, narrowing in its connection with the condenser when arranged alongside of cylinder.

DOUBLE-PORTED VALVE.

This valve is now generally adopted. It is worked direct from the shaft by double eccentrics and link motion. Valve is placed on edge, the rubbing edge

having a large surface for wear. The valve is cast with a centre rib dividing all the ports—this rib is simply to strengthen the valve. The thickness of valves for 25-inch cylinder being $\frac{5}{8}$ inch, and for 63½-inch diameter $1\frac{1}{8}$ inch. The back of the valve has



Slide Valve and Casing.

a raised planed surface, and the valve casing cover is cast with an annular recess, truly turned and fitted with brass rings and set screws, arranged thus:—Brass ring against back of valve, then gasket space, then another ring of brass or wrought iron, which being pressed upon with the set screws, makes the ring in contact with the valve steam-tight. The diameter of annular recess should be as large as convenient for 63½-inch cylinder, the mid-diameter or centre of set screws will be 36 inches diameter, the breadth of rings $1\frac{3}{4}$ inch, and depth of recess multiply the breadth by 2, thickness of rings $\frac{5}{8}$ inch. The set screws $\frac{3}{4}$ inch diameter, with jam-nuts and washers. The valve-casing is an open casting, having merely sides and

ends. Thickness for a 25-inch cylinder $\frac{3}{4}$ inch, and for 63½-inch cylinder 1¼ inch, the flange ¼ inch more. The steam-pipe is at one end, and steam-passage tapering to the extreme end, inside flanges top and bottom, and outside flanges at end, for securing the cylinder.

PISTON-ROD.

To find the diameter of piston-rod, multiply the area of piston by the pressure (*i.e.*, steam and vacuum), dividing the product by 2,240, and the result gives the area of rod in square inches for compressive strain. Steam pressure, say 20 lbs., and 12 lbs. vacuum = 32 lbs. total pressure.

$$\frac{3{,}170 \times 32}{2{,}240} = 45 = 7\tfrac{5}{8} \text{ inches diameter.}$$

For tensional strain where cotters are used, or where the piston is attached to rod by a nut—divide the piston area into pressure by 4,000, and the quotient gives the section at the bottom of the thread. Where two piston-rods are used for return piston-rod engines, add ¼th more, or two rods 6 inches diameter nearly.

Depth of stuffing-box, from inside of cylinder end to flange face, equals the diameter of piston-rod, multiplied by 2; breadth of packing space equals the diameter of rod divided by 4; the thickness of stuffing-box flange equals the rod divided by 3; from two to six bolts for screwing up packing from 25 to 63½-inch cylinders; when two piston-rods are adopted,

for bolts as for a 6-inch rod, to find the area of bolts, divide the piston-rod area by 6, and the quotient will give the area of all the bolts.

$$\frac{28{\cdot}27}{6} = 4{\cdot}71 \div 4 = 1{\cdot}17 = \text{(say) } 1\tfrac{1}{4} \text{ inch each bolt.}$$

SLIDE-VALVE ROD.

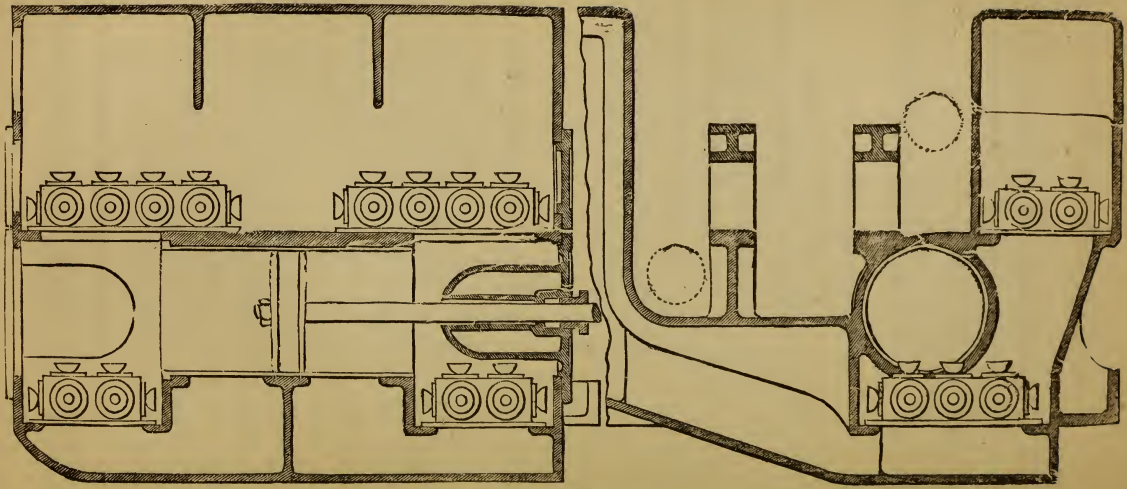
The diameter of slide-valve rod depends on the size and weight of valve, by multiplying the full area of valve by the pressure as for piston-rod, adding the weight of valve in lbs., and dividing the result by 2,240, then taking one-sixth of the quotient, equal the area of valve-rod in square inches at the weakest part. Say 1,764 area of valve face, and weight of valve 1,600 lbs.

$$\frac{1{,}764 \times 32 + 1{,}600}{2{,}240} = 25{\cdot}9 \div 6 = 4{\cdot}3.$$

Say $2\frac{5}{16}$ inches diameter at the bottom of the thread, and attached to valve with a T nut; the nut in slide-valve should have play in direction of wear of valve, and when the valve is accurately set a jam-nut or rod is secured tight up against T nut. Sometimes two rods are adopted, passing over shaft on the return principle, the link motion being guided on condenser; in this case the rods should be at least 2 inches in diameter, same proportion of gland as for piston-rod, two bolts for screwing up packing.

AIR-PUMP, CONDENSER, ETC.

The capacity of air-pump equals the $\frac{1}{4}$th part of



Air-pump, Condenser, &c.

the cubic contents of cylinder, for double action, and double that quantity for single action, the stroke the same as for steam-cylinder, the air-pump rod being attached to steam-piston by a nut, and connected to Muntz's metal rod on air-pumps, by a socket and cutter. To find area of air-pump divide the cylinder area by 11 for double action, and 5·5 for single action, $\frac{3,170}{11} = 288 =$ say 19 inches diameter for double action. The lining of gun-metal for air-pumps varies from $\frac{1}{2}$ to $\frac{3}{4}$ of an inch, according to size; the air-pump piston of gun-metal, with metallic packing of the same material, with junk ring, open at one end, having ribs radiating from centre boss. Some employ a plaited gasket instead of metallic rings; however, I think a plain piston fitted with "Ramsbottom" rings would make an excellent substitute. The depth of piston equals the diameter divided by 4.

$$19 \div 4 = 4\tfrac{3}{4} \text{ inches.}$$

When the valves are so arranged as to leave a large water space at ends of pump, the space is partially filled up with a cylindrical casting formed on the covers, so that there may not be so much dead water left in pump. The diameter of air-pump rod equals the diameter of pump divided by $7 = 2\frac{3}{4}$ inches—the gland having the same proportion as for piston-rod. The area of foot-valve passage in condenser equals the area of pumps, and for head-

valve passages multiply the area of pump by 1·35—288 square inches for foot-valves, 288 × 1·35 = 388 square inches for head-valve. This result is only for one end, and the valves are so arranged that they may fit either end. Some prefer inverting the foot-valves, and so placing them that the water in condenser is above the pump. The areas of foot and head valve passages in condenser are greatly reduced by the gun-metal valve seat—a good description of valve of the double-flap type, having the vulcanised india-rubber secured to the seating by stud-bolts in the centre line of valve, thus forming a flap-valve on each side, having guards secured with the same studs. By this means a greater strength of rubber is obtained. The holes in each for the passage of the water are hexagonal, formed around circles of 1 inch diameter; the webs at top bare $\frac{1}{4}$ inch broad, tapering to $\frac{1}{8}$ inch at the underside, the thickness of seat varying from $\frac{3}{4}$ inch to 1 inch for extra size, and having side flanges somewhat less in thickness for securing seat to condenser. The area through foot-valve grating should be nearly that of pump area multiplied by ·61, and for head-valve by ·83—

288 × ·61 = 175 sq. in. for foot-valve (or suction),

288 × ·83 = 239 sq. in. for head-valve (or discharge).

Care must be taken to have the combined area of hexagonal holes as large as possible, and the valve opening, or angle of the guards equal to the full area. A small lift, however, is better for the wear

of the india-rubber, but can only be attained by an increased number of valves.

Other valves, such as round discs, find favour. This species of valve takes up a great deal of room. However, by making the valve a hollow square box, five valves can be introduced into as little space as is usually occupied by one, by placing a valve on the top, and one on each side of square, the bottom being open; thus a large area is obtained with a moderate lift of valve. The valve seats are secured to the condenser in the valve chamber with $\frac{3}{4}$-inch stud-bolts and nuts of Muntz's metal, and the large holes in the condenser are strengthened with a bridge in the centre line of the valve seat. The capacity of the condenser when placed alongside of the cylinder, no matter what form it may assume, is found by multiplying the capacity of the cylinder by 1·3, and the result gives the capacity of one condenser—

$$66 \text{ cubic feet} \times 1{\cdot}3 = 85{\cdot}8 \text{ cubic feet}$$

for one condenser. This result is greatly in excess of what is generally acknowledged, but nevertheless most makers adopt about the same proportion. Of course, when the condenser is placed on the opposite side of cylinder in relation to crank-shaft the capacity can be reduced, as the eduction-pipe will then form a large portion of the contents. The condensers are then separate castings, with one discharge-pipe common to both. The area of discharge-pipe equals the area of air-pump, or half of the area

for each—288 square inches = 19 inches diameter, or 144 square inches = 13½ inches diameter, or nearly so. The thickness of condenser varies from ¾ inch to 1¼ inch; if with large flat surfaces it is strengthened with ribs, the part above head-valves forming an air vessel; the diameter of snifting-valves varies from 2½ inches to 4 inches, and is placed as low as possible, so that all the air, &c., may be discharged from condensers in the act of blowing through.

SURFACE CONDENSATION.

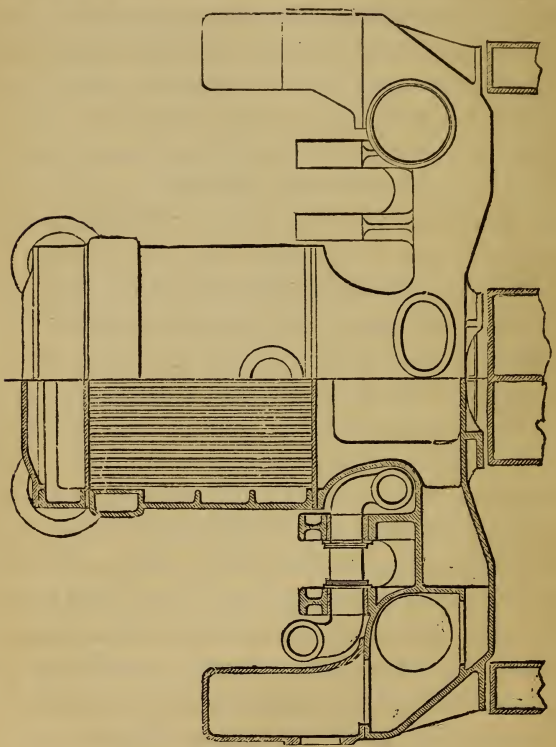
Hall's system of surface condensation renovated has as yet proved but a partial success. When first introduced, the copper tubes were found to choke up with a deposit from the sea water and coagulated tallow taken over by the steam from the cylinders, thus lessening the conductive power of the copper. Since then it has been discovered in some cases that copper tubes become pitted and riddled with small holes. Here we have two evils, if no material can be discovered to resist the deposit forming. In course of time the surface would become comparatively useless; and in like manner, if the galvanic action, &c., or pitting, cannot be prevented, the condenser would then be turned into an ordinary injection one, with thousands of small holes, through which the sea water would be forcibly injected into the condenser. Some faith

seems now to be placed in cold-drawn composition tubes.

Some time back I stated that tubes nine-sixteenths of an inch diameter, and of exceeding light gauge, were not calculated to resist any great strain; since then I have seen tubes completely riddled with small holes, and a hard deposit formed from the sea water, and considered that with an internal bore of seven-sixteenths of an inch full, and say 5 feet long, any amount of scraping would render them completely useless, no matter what the material is. Some maker divided the tubes into three rows, thus scouring the water from circulating-pump three times through, the area of exit being reduced accordingly. This is to a certain extent required, as the forced water would no doubt have a tendency to go through the bottom tubes, therefore doing more duty than the top ones; but I consider it a more profitable arrangement to divide the water from pump before it goes through the tubes. The cold water would thus be circulated and the full area of tubes attained, as I have no doubt when water is forcibly ejected or drawn through small areas the mere friction of the water will tend to wear the tubes (as may be seen in bends of brass taps for drawing off water direct from a high-pressure main).

However, as a precaution, the ordinary injection-valves are fitted so as to turn the condenser into a plain injection one, with a discharge-pipe overboard.

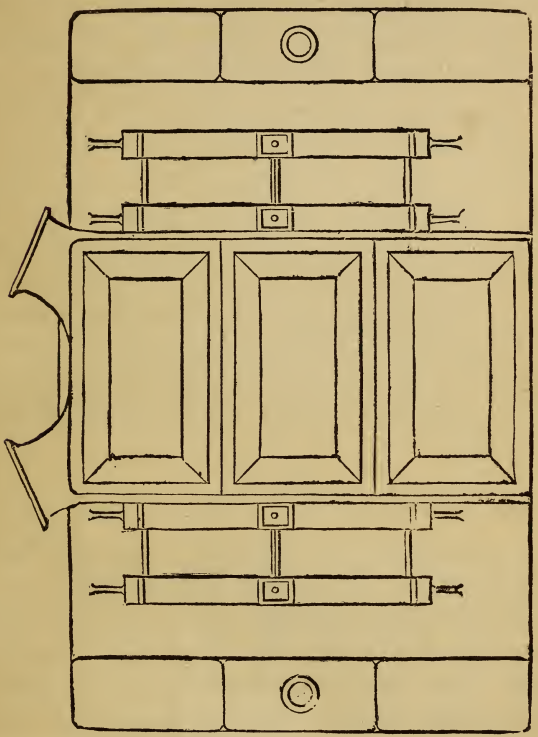
The cooling surface of tubes is about 14 square feet per nominal horse-power; and it is evident what would do for the tropics is ample for more northern



Surface Condenser.

climes. Medium tubes, $\frac{3}{4}$ inch in diameter, circulating and air-pump double action, the same size as for plain injection, namely, 19 inches diameter

for 400 nominal horse-power; this may appear large, but in cases of failure or break-down with the sur-



Surface Condenser.

face system the pumps must be capable of doing duty, as with plain injection.

In the event of great leakage in a vessel, as the bilge water in the surface system cannot be turned

into the condenser, it is necessary to fit the circulating-pump with a sluice-valve and pipe to draw the water from the bilge. The pipe from the sea should likewise be fitted with a sluice-valve for shutting off the sea water. Should both the pumps be used as air-pumps, in cases of failure, the condenser ought to have a separate bilge-injection fitted to it. When a separate centrifugal-pump is used, driven by a small engine, and two air-pumps, the centrifugal-pump can be arranged to pump the bilge water direct overboard, and one of the air-pumps turned into a circulating-pump, the sluice-valves for doing so being placed so as to be opened at the shortest notice. A valve is fitted to some convenient part of the condenser to drain all the water off when necessary.

SEA EXPERIENCE WITH SURFACE CONDENSATION.

"Perhaps the most successful," says Mr. Robert Murray, C.E.,* in a recent communication to the Naval Architects' Institute, "are examples at Southampton, afforded by the Royal Mail Company's large screw steamers, *Rhone* and *Douro*, each of 3,000 gross tonnage and 500 horse-power, which burn about 35 tons of coal per day, at an average speed of 10½ to 11 knots. Having recently examined the boilers of these two vessels, I can testify that

* Author of the "Treatise on Marine Engines and Steam Vessels," No. 80, of the "*Weale Series.*"

they show not the least appearance of any undue corrosion going on, after having run some 80,000 miles. Mr. Hugh Arthur, the intelligent engineer of the *Douro*, has kindly furnished me with the following account of his treatment :—

"'The pressure of steam in the *Douro* is 20 lbs. It is super-heated, and admitted into the cylinder at about 304 deg. Expansion takes place in the cylinder for about two-thirds of the stroke. The condensers are generally worked at a temperature of 118 deg., when the vacuum is 26½ inches by the gauge, and 24½ inches by indicator card. Within the tropics, with the sea at 82 deg., the condensers are worked at 126 deg., the gauge showing a vacuum of 25 inches, and the indicator 23 inches. The temperature of the discharge water varies from 16 deg. to 20 deg. less than the temperature of the condensers.

"'On the first voyage every precaution was taken to get sufficient scale over the boilers to protect them, if possible, from the destructive effects so manifested in boilers using surface-condensation. The density at which they were worked during this voyage was one thirty-second and a half of salt. After running over 5,000 miles, an opportunity offered for examining them, when everything was found to be going on well, a thin scale having formed on the furnace tops and tubes. After another run of over 5,000 miles with the water in the boiler

at the same degree of saltness, it was found that sufficient scale had formed to answer the required purpose, and the water was then reduced to about the density of sea water, or one thirty-second of salt, at which the boilers continue to be worked. Up to the present time there is little or no alteration in them, for when the scale is found to increase or decrease, the density at which the boilers are worked is altered accordingly. Every four hours a small quantity of water is blown off through the brine-cocks, thus causing a gradual change of water, which is found to be necessary. Also when arrived at any port, instead of letting off the steam by the waste-steam pipe (which only increases the density of the water), we have them blown down and pumped up again with the donkey-engine, which gives a change of water without any extra cost. The only cleaning which the boilers require is to sweep off a fine brown powder that gathers about the steam chests and up-takes, these parts being afterwards coated with boiled oil between every voyage.' "

"It should be stated that the *Rhone* and *Douro* have the great advantage of ample boiler-power, to which circumstance, as well as to the moderate speed at which they are driven (about 10½ knots), must in a great measure be attributed the remarkable economy they exhibit. As an extreme case on the other side, the *Normandy*, channel packet between Southampton and Hâvre, burns forty-five tons of coal per day of

twenty-four hours, although she is only 425 tons burthen, with engines of 220 horse-power, fitted with surface-condensers; but then she is driven at from 13½ to 14 knots per hour."

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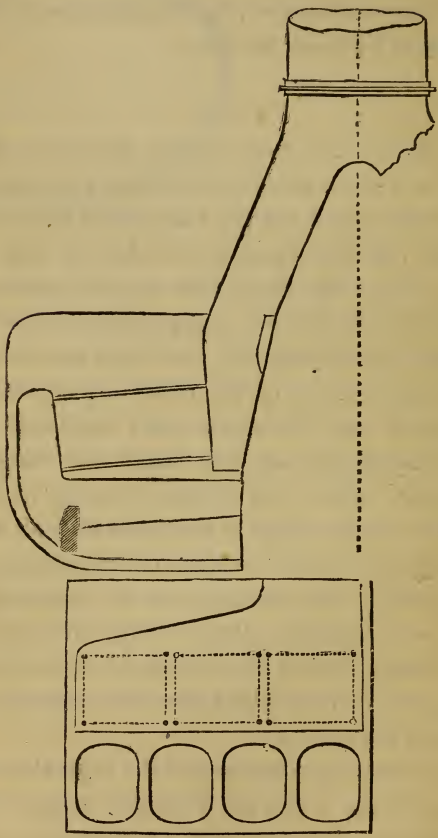
BOILER.

As it is my intention to point out how work progresses in the workshop, and as I may say the foreman pattern-maker has got the bulk of the work in hand, so the draughtsman can fill in the small details. Any little strips that may be required can be placed on the patterns when they are about ready to be sent into the foundry. So I will turn attention to the requirements of the boiler department. In all ships of war the boilers must be placed below the orlop-deck, or one foot below the water-line. The boilers are of two classes, namely, high and low. In very fine ships it is often a difficult matter to arrange the boilers to meet the requirements for great power. The arrangement is stokehole fore and aft, with furnaces athwart ship, with over-head return tubes; and for the low-class boilers furnaces running fore and aft, with tubes athwart ship on the same level as furnaces.

For 400 nominal horse-power the high-class boiler is adopted—the width of stokehole from front of furnaces being 10 feet, and the width at top of boilers 7 feet; the width from front of furnaces to back of boiler (in this case) 10 feet, height

11 feet, and length 12 feet 9 inches; and four boilers, each 100 horse-power; from top of boiler



Boiler, 4 off.

to top of flues, not less than 3 feet 6 inches; so

as to insure ample steam room, the area of fire-grate per horse-power equals ·68 square feet; heating surface per horse-power, 18 square feet, and in some cases even more than this is demanded; area of funnel, 10 square inches per horse-power; from bottom of boilers to bottom of furnaces, 6 inches; from bottom of furnaces to top of furnaces, 3 feet 6 inches; the length of fire-grate should not exceed, if possible, 6 feet 6 inches, allowing for a dead plate 6 inches from front of boiler; the width of furnaces should not be less than 2 feet 6 inches, and certainly not exceed 3 feet 3 inches. It must be acknowledged by all that marine boilers should have as many furnaces as possible, bearing in mind that the length must not be out of all proportion to the width, so that the firemen may be able to keep the fires in proper trim. For instance, some would place three furnaces in each boiler, 3 feet 5 inches broad, while others would have four furnaces, say 2 feet 7 inches broad. In the former they effect a saving of material, namely, two sides; and in the latter two additional sides are required, and an extra water space, but with what result? The fire-box of a locomotive boiler, that is the sides and top, exposed to the live coal, is the most effective heating surface. So it is with marine boilers. The most surface exposed to the live coal must be the best steam-producing boiler, and in the act of firing less cold air is admitted, for there can be no doubt that with an

opening 3 feet 5 inches wide, the body of air admitted by the furnace door and underside of fire-bars tends in a great measure to damp the other two fires.

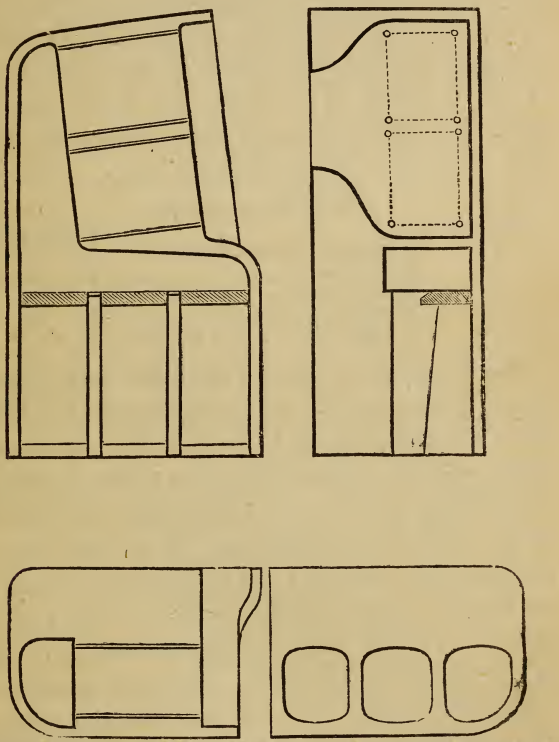
The brass tubes are $2\frac{1}{2}$ inches in external diameter, thickness No. 12 wire gauge, length in this instance 6 feet 6 inches, and the pitch of tubes $3\frac{1}{2}$ inches; the average length of tubing per horse-power equals 24 lineal feet.

Thus far the height of furnace is set off, and the height of boiler, and distance of top of flues from top of boiler; so now the designer may determine the top and bottom line of tubes—an allowance of half an inch per foot in length being the inclination of tubes. The draughtsman will find it very convenient to rule a clear piece of parchment in squares, according to the scale adopted, those squares representing the pitch of the tubes. As there are four boilers, each 100 horse-power, and as the tubes are 6 feet 6 inches long—

$$\frac{100 \times 24}{6{\cdot}5} = 369 \text{ tubes in each boiler,}$$

a little more can be given if necessary. Apply the parchment to the drawing, and it will at once determine the space required; an allowance must be made if the tube plate is in two pieces. If the designer can get the amount of fire-grate in the space, this determines the length of boiler. For precaution he must run out the total heating surface, so as to have

18 square feet per horse-power. The distance between furnaces, 6 inches; and at sides, 5 inches. The outer shell of boiler in the direction of furnaces should be



Low Boilers, in H.M.S.S. *Icarus*.—330 brass tubes, $2\frac{1}{2}$ inches diameter, $3\frac{1}{2}$ inches centres.

quite flat, but around the boiler, at top and bottom of back, the plates can be curved as occasion may

require. The fire-box width at top of tubes not less than 1 foot 6 inches. This is required so as to give room for the workmen to make the tubes tight, or driving in the ferrules. The contents of steam room 4 cubic feet per horse-power (while in a low boiler, taking up a length fore and aft 19 feet 6 inches, and 21 feet 6 inches of the beam, and 7 feet 3 inches high, the contents of steam room is about six cubic feet); this is for 150 horse-power:—

THICKNESS OF PLATES.

Thickness of shell	$\frac{3}{8}$	of an inch.
„ bottom, and bottom of fronts	$\frac{7}{16}$	„
„ tube plates	$\frac{5}{8}$	„
„ furnaces	$\frac{7}{16}$	„
„ up-take	$\frac{1}{2}$	„

Angle-iron, $3 \times 3 \times \frac{1}{2}$ at root.

The diameters of rivets, $\frac{3}{4}$ of an inch and 2 inches pitch. Some plate the boilers haphazard; it is a bad plan; the plates should be ordered for the particular boiler required, and all the plates as far as possible even dimensions; this is obvious from the pitch of rivets. All the flat plates can be at once sent to the punching machine; no templating is required, the multiple punch and the travelling table perform their work in the most accurate manner, the edges of the plates being planed. Diameter of stays $1\frac{1}{4}$ inch, with screwed ends $1\frac{1}{2}$ inch diameter—this is to pass the stays easily from one side to the other; nuts inside and out; the pitch of stays 16 inches; the fire-bars of wrought iron, 3 inches deep, $1\frac{3}{8}$ at top and $\frac{1}{2}$ an inch at bottom, with $\frac{1}{2}$-inch spaces

between; inclination of fire-bars $1\frac{1}{4}$ inch to the foot.

TELESCOPIC FUNNEL.

The funnel will be 10 square inches × 400 = say 6 feet diameter, the thickness of sliding part $\frac{1}{8}$ inch at top and $\frac{3}{16}$ at bottom, surrounded with the necessary air-casings, &c. The funnel is raised and lowered like any other weight, but the usual plan is to secure chains to bottom, and then pass them over pulleys on top of outer casing. The chains then go downward to top of boiler, to which is fixed the chain barrels and purchase,—a worm wheel and pinion being the best method, as the funnel can never slip down with this arrangement. When the funnel is full up, set screws jam it up, and then the funnel shrouds are secured on deck. The smoke from boilers is conveyed by the dry up-take, or "lumleg," shaped like the letter ∨ inverted ∧; the height from top of boiler 6 feet 6 inches, and the height where it rounds into the funnel 9 feet 6 inches. This is to promote free circulation in the stokehole. In any class of boiler, joining the steam chest over the fireman's head is an arrangement that should never be attempted.

COAL-BOXES.

An allowance of 46 cubic feet per ton of coal is given for stowage, 6 inches from under-side of

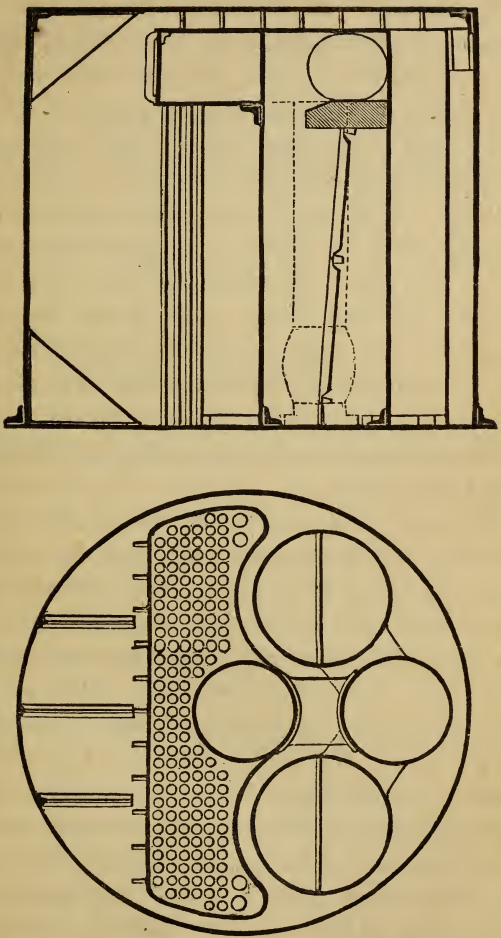
deck beams to be left out in the calculation. Side plates $\frac{1}{8}$ inch thick, bottom plates $\frac{3}{16}$ inch thick, corner angle-iron $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$, stay angle-iron $2 \times 2 \times \frac{5}{16}$, stayed every 3 feet apart.

HIGH-PRESSURE BOILER.

The object of this arrangement is to promote a free circulation of the water, with as little dead water at the bottom of boiler as possible, the flame from furnaces dipping down into the bottom combustion chamber, conveying the flame and heated gases to the front of boiler, ascending into the top chamber, through which it passes, and then returning through the small tubes. With the object of burning the smoke, small air-tubes pass through the water from the front of boiler, and meet the flame as it dips down into the bottom chamber, thus assisting combustion. This plan of burning the smoke has been successfully carried out in double-flue Cornish boilers, with good results.

FEED-PUMPS.

As the number of cubic inches of water varies according to the pressure of steam, and as a cubic foot of steam requires a certain amount of water, a table of the relative proportions of water to steam is required. 2·25 is the number of cubic inches of water necessary to raise a cubic foot of steam at a pressure of 20 lbs



High-pressure Boiler.

To find the water required multiply the cubic contents in feet of steam in one cylinder for an entire revolution by 2·25, and the result will give the contents of a single-acting pump in cubic inches—132 × 2·25 = 297 cubic inches; this result is only for one cylinder, and most makers give double the contents. So if one of the pumps requires adjusting, the other one is able to keep up the supply—297 × 2 = 594 ÷ 36 stroke = 16·5 = 4½ inches diameter for each pump. The pumps for return connecting-rod engines are worked off piston-rod, an arm being keyed on for that purpose. The plunger, or ram, having an inside sliding-rod, with thumb-screw on plunger, so that the pump can be disengaged at any time.

The valve-box is generally placed at the end of pump, the arrangement of relief and delivery valve on the same level, and the suction-valve placed below the relief-valve, the valve-box being of gun-metal, this plan requiring no separate valve seats; however, india-rubber valves are now coming into use. For the area of valves, see rule for air-pump, &c. When of brass, 3-inch valves will be sufficient for this size. A cock for shutting off the suction is fitted to valve-box, and the relief passages are formed in condenser, conveying the water above the head-valves (that is when the pump-barrel forms part of the condenser casting); the relief-valve is held down with a spiral spring, fitted with

set-screws. The bilge-pump is the same size as the feed-pump, the suction-pipe being fitted with a perforated mouthpiece.

PROPORTION OF WATER TO STEAM.

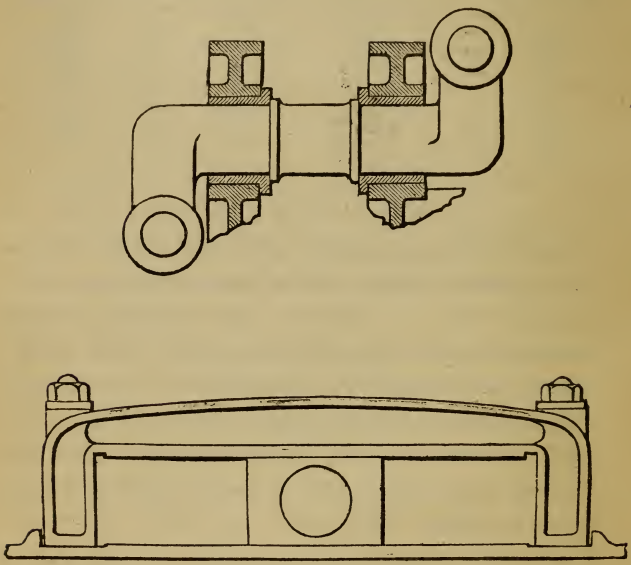
Pressure of Steam per Square Inch.		Cubic Inches of Water in a Cubic Foot of Steam.	Pressure of Steam per Square Inch.		Cubic Inches of Water in a Cubic Foot of Steam.
1	=	1·099	45	=	3·700
5	=	1·350	50	=	3·981
10	=	1·658	55	=	4·256
20	=	2·258	60	=	4·535
25	=	2·552	65	=	4·812
30	=	2·842	70	=	5·052
35	=	3·130	75	=	5·317
40	=	3·415			

GUIDES AND CROSS-HEAD.

The best arrangement of guides for double piston-rod engines is double-motion bars, on the same line as centre line of cylinder; the cross-head being round for the connecting-rod, and guide-blocks having arms forged on for taking the piston-rods. The diameter of cross-head is found by dividing the total pressure on the piston by 1,400, and the quotient gives the area of cross-head, this being ample for all—

$\frac{3{,}170 \times 32}{1{,}400} = 72$, say $9\frac{1}{2}$ inches diameter; the width of each block for taking the upward and downward thrust of the connecting-rod (the latter, of course, or downward, being the go-a-head motion bar) equals the diameter of cross-head, and the length multiply the diameter by 2. The blocks are of brass or cast-iron, lined with white metal. The

depth of the top motion-bars, or guides, equals three-fourths of the diameter of cross-head. Some allow clearance between the blocks and guides, depending on the weight of the cross-head and adjuncts; to neutralise the thrust, however, one-eighth of the



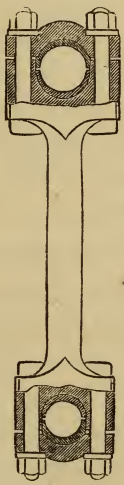
Guides and Cross-head.

total pressure on piston can be safely taken for calculating bolts, &c.; the motion-bar being taken as a beam having a section, or centre rib, with flanges top and bottom. Of course the thrust varies according to the angle of inclination, the longer the connecting-rod is, the more the thrust diminishes,

a proportion of $4\frac{1}{2}$ to 5 times the radius of crank being about the average length of connecting-rod.

CONNECTING-ROD.

The thrust and pull on the connecting-rod receive the full pressure from the piston, and the same rule holds good as for the piston-rod, namely, 2,240 for



Connecting-rod.

compressive, and 4,000 for tensional strains. Thus the diameter at ends will be $7\frac{5}{8}$ inches; an allowance of one-fourth of an inch in diameter for every foot of length gives the diameter at middle. The most approved form is to have solid ends, forged in a piece, fitted with brasses and caps. The thickness

of caps is one-half of the diameter of rod. The combined sectional area of bolts, at the bottom of the threads, is found by dividing the total pressure on piston by 4,000. Where straps are used the combined area must equal the area of rod, an allowance being made for jibs and cutters. The breadth of cutter equals the diameter of rod, and the thickness is found by multiplying the diameter of rod by ·31. The thickness of brasses is found by dividing the diameter of crank-pin by 8, and for the sides divide the result by 2. The brasses are planed out and lined with white metal, the proportion being $1\frac{1}{4}$ inch of brass surface all round with a mid strip.

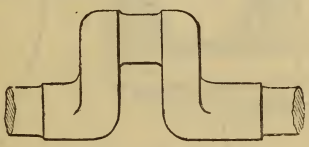
MAIN CRANKED SHAFT.

I adopt this term to point out the difference of a shaft cranked, or forged in a piece, and a plain one, although the same rule holds good for both, the strain being simply torsional. By multiplying the length of crank in inches by the total pressure on the piston, and dividing the sum by 1,206, the cube root of the quotient will be the diameter of shaft—

$$\frac{3{,}170 \times 32 \times 18}{1{,}206} = \sqrt[3]{1{,}514} = \text{say } 12 \text{ inches diameter.}$$

The collars for this size may be 1 inch, making the large part of shaft for receiving the eccentrics, &c., 14 inches in diameter; the length of the two outside journals equals twice the diameter of journal. The

middle one is generally made longer, according to the distance between centres of cylinders. The crank-pin is the same diameter as the journal; the distance between the jaws of crank is found by multiplying the diameter of journal by ·87, and equals say $10\frac{1}{2}$ inches. The thickness of cranks, in the direction of the length of shaft, is found by multiplying the diameter by ·8,=say $9\frac{1}{2}$ inches, and the breadth equals the diameter of shaft beyond the



Main Cranked Shaft.

journals, namely 14 inches. All the collars should have a bold radius at the journals, as when they are cut square in, that will be the point where the cranked shaft may break in course of time.

CUBE ROOTS OF NUMBERS.

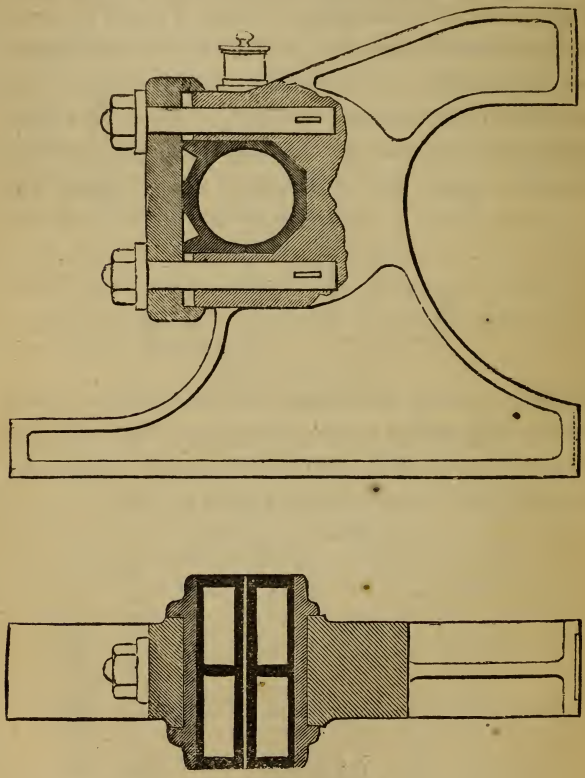
Arranged for Shafts advancing in diameter $\frac{1}{2}$-inch.

Nos.	$\sqrt[3]{}$	Nos.	$\sqrt[3]{}$	Nos.	$\sqrt[3]{}$	Nos.	$\sqrt[3]{}$
8	2·0	512	8·0	2744	14·0	8000	20·0
15	2·5	614	8·5	3048	14·5	8615	20·5
27	3·0	729	9·0	3375	15·0	9261	21·0
42	3·5	857	9·5	3723	15·5	9938	21·5
64	4·0	1000	10·0	4096	16·0	10648	22·0
91	4·5	1158	10·5	4492	16·5	113 0	22·5
125	5·0	1331	11·0	4913	17·0	12167	23·0
166	5·5	1520	11·5	5359	17·5	12977	23·5
216	6·0	1728	12·0	5832	18·0	13824	24·0
274	6·5	1953	12·5	6331	18·5	14706	24·5
343	7·0	2197	13·0	6859	19·0	15625	25·0
421	7·5	2460	13·5	7414	19·5	16681	25·5

The decimals are left out in the above numbers.

MAIN FRAME.

The main framing is subjected to tensional and compressive strains, and, I may add, twisting, there-



Main Frame.
Within the black space is the white metal.

fore should be a stiff section. A good form is a centre rib, with flanges top and bottom. As the cohesive

strength of cast iron is less than that of wrought iron, in the ratio of one of wrought iron to three of cast iron, it is evident that the combined area of framing, at the weakest part, should not be less than three times the area of the two piston-rods, or the combined area of piston-rods in both cylinders—that is to say at their weakest part. Indeed, as the main framing forms the "backbone" of the engine, experience has taught us that more is required. The framing is open, and is bolted to cylinder top and bottom, the bottom limb of frame being carried along to condenser and bolted to it, and the bottom flange running in a line with the flanges on cylinder and condenser, all of which are strongly bolted down to engine keelsons. The brasses for crank shaft are just the ordinary plummer block arrangement, laid on the side with wrought iron or cast-iron cap, with "clips" to embrace ends to prevent springing. There are two bolts to each cap, and three frames, making six bolts in all. The breadth of frame equals the diameter of shaft at journals, namely, 12 inches, the depth of top limb 12 inches, while that of the bottom one is three-fourths, 9 inches deep. The thickness of centre web for 25-inch cylinder is seven-eighths of an inch, and for 63½-inch cylinder 1¾ inches; the flanges for bolting down to keelson, and to cylinder, and condenser, one-fourth more, and all the other flanges one-eighth less than the centre rib. The depth of cast-iron for the

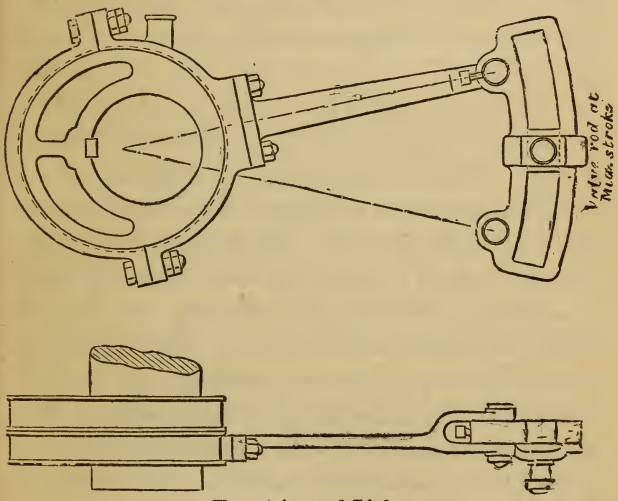
bottom of brasses is one and three-quarter times the diameter of shaft at journal, measured from the centre of shaft to bottom of block. The limbs spring from this part, for connection with cylinder, and the centre web is carried down to the bottom or keelson flange, joining to condenser with limb 7 inches deep. The thickness of brasses at bottom is one-seventh of the diameter of journal, say $1\frac{3}{4}$ inches. The diameter of cap bolts is found by multiplying the combined cylinder areas by the pressure, as for piston-rods, &c., namely 32 lbs., and dividing the result by 4,000. The quotient gives the area of all the bolts—

$$\frac{3{,}170 \times 2 \times 32}{4{,}000} = 50{\cdot}72 \div 6 \text{ bolts} = 8{\cdot}45$$

square inches area at the bottom of the threads. The bolts are fixed into block with cutters $3\frac{1}{2}$ by $\frac{3}{4}$ inch thick; the area of the bolt at this part must equal the area at bottom of thread, adding the area of key-way thereto. The caps when of wrought iron are one-third of the journal diameter, and when of cast iron, one-half of the journal in thickness. The brasses are recessed out about $\frac{1}{4}$ of an inch deep, and filled in with white metal, the brass surface being $1\frac{1}{2}$ inch broad all round, with a strip of the same breadth running lengthways at the bottom of the brasses.

ECCENTRIC STRAP, ROD, AND LINK.

The bolts for the eccentric strap are found by multiplying the total area of the slide-valve, adding the weight of valve, by the pressure, as for piston-rod, and dividing the result by 4,000; then, one-sixth of the quotient, divided by 2, will give the area of each bolt at the bottom of the thread:



Eccentrics and Link.

find in a table of areas the diameter to correspond, then add the depth of the thread, which will then give the full diameter. The breadth of strap equals twice the diameter of bolt. The sectional area of strap of gun-metal should be three times the area of bolt at the bottom of the thread; this is where it is bolted

together, and is slightly increased in thickness all the way round. The thickness of snugs equals one-fourth more than the thickness of strap. The thickness of the boss on eccentric equals one-seventh of the diameter of shaft; and the thickness of eccentric ring one-eighth of the diameter. The eccentrics are cast open, with a rib between boss and ring. The pins for eccentric-rods are the same diameter as the slide-valve rod, forked at the link end, with a T end for attachment to eccentric strap; the rods are flat, the smallest end equals the area of valve rod, and for every foot of length add half an inch to the breadth of rod. Bolts for attachment to strap are of the same diameter as for the strap. The slotted or open link is generally adopted. The distance between the eccentric rods or links equals three times the throw of eccentric. The holes for receiving the pins are fitted with brasses and set-screws. The diameter of the slide-block pin is found by multiplying the slide-valve rod area by 1·3, which gives the area of pin. The pin is tapered and fitted with a tapered split ferrule of steel, having set-screws and nuts on pin for adjusting the wear. The slide-block is of brass, with loose side-flange and screws; the length of the block equals twice the diameter of pin. The point of suspension on link is midway between the eccentric-rod pins, on the radius line of link, a cross bar with pin being riveted thereto. The width of the link should be one-sixth more than the diameter of slide-rod. The

sectional area of link equals that of the slide-block pin. The sliding block or cross-head, to which the pin is secured, is generally a flat bar, moving on suitable guides of brass, the cross-head having a lug forged thereon for securing slide-valve rod. The suspension-pins are found by dividing the valve-rod area by 1·6, which gives the area of the pin, the suspension-rods being fitted with brass bushes. The diameter of rods at ends equals the diameter of pin.

POWER REQUIRED TO MOVE SLIDE VALVES.

The most approved form of starting or reversing gear is when the starting or hand-wheel turns a worm-wheel gearing into a pinion, the pinion shaft carrying the reversing lever. Other forms are adopted, such as a plain spur-wheel and pinion. I will take an example from practice, with two valves, having their combined areas equal to 1,458 square inches. The diameter of starting-wheel, where the hand grips the handles, is 30 inches; the pinion, on the same shaft, is 3 inches diameter, of wrought iron solid on shaft; and the spur-wheel 18 inches diameter at the pitch line; the radius of reversing lever 7 inches = 14 inches diameter; this is for an engine of 150 horse-power. Thus we have

$$\frac{30 \times 18}{3 \times 14} = 12{\cdot}8, \text{ or nearly } 12\tfrac{3}{4} \text{ to } 1;$$

this being the power given off at the suspension-pin,

or pin on which the link oscillates. Now, taking this as a data, all others must vary as the areas of the valves. Suppose less is required for, say 836 square inches combined area—1,458 : 12·8 : : 836 = a power of 7·3 to 1 ; for 400 horse-power, the combined area of valves say 3,528 square inches—1,458 : 12·8 : : 3,528 = a power of 30·9 to 1.

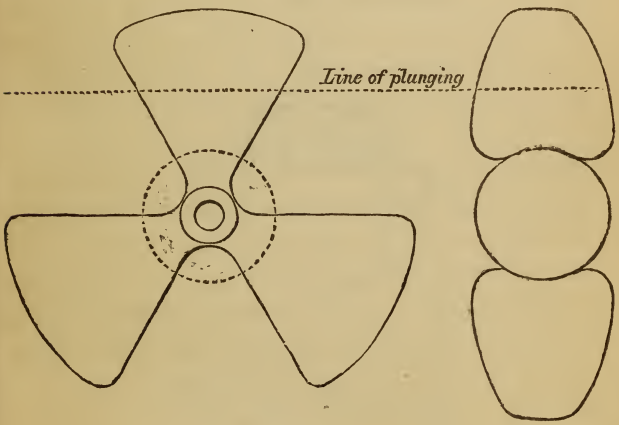
HAND GEAR.

The blow-through, injection, and throttle-valve handles, should be placed all in a row, as near the starting-wheel as convenient. Some arrangements have a central rod for blow-through, a hollow rod or tube over that for injection, and another over that for throttle-valve, as the case may be. The proportion of rods is as follows: long rods must be either supported at the middle, or be unnecessarily large in diameter; such rods rarely exceed 1 inch in diameter at ends. The joint pin is of the same diameter as at ends, and the diameter of the eye equals the diameter of pin, multiplied by 2, and the depth of the boss of eye equals the diameter of pin. This is for single joints, which should always be adopted when convenient, as they are much cheaper ; but when double joints are used the distance between the jaws of joint equals that of the pin's diameter, and thickness, one-half of the diameter at the weakest part.

SCREW-PROPELLER.

Screw-propellers are of two kinds, namely, com-

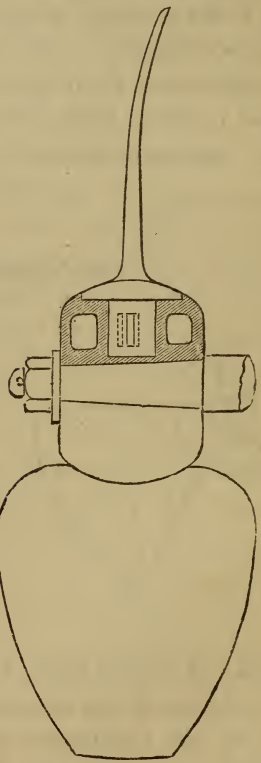
mon and feathering. With the former the blades of the screw are cast solid on the boss, while those of the latter, known as Griffith's, are made to feather. The pitch, according to the inventor, should vary from 1 to $1\frac{1}{2}$ of the screw's diameter. The screw's disc, or area of a circle, represented by the diameter of screw, should have about 1 foot for every 2·75 square feet of midship area or immersed section, but the actual



surface of the blades of the two kinds, I cannot better explain than by reference to the wood-cuts.

The inventor of the two-bladed screw argues, and justly, that the angle of the blades of the common screw at the centre, as shown by the dotted lines, only disturbs the water, throwing it off at right angles to the path of the vessel. The true

merit, therefore, of this invention is filling up this area with a spherical boss, thereby reducing the vibration that is felt with a common screw, and



"Griffith's" Screw-propeller. (For proportions see page 77).

giving facility for repairs, or putting on a new blade. The boss may be considered damage-proof. There can be no doubt when a vessel plunges in

a heavy sea, that a three-bladed screw is preferable to a two-bladed one, as the blades have more hold of the water. The common screw is keyed on the end of shaft, the hole having a taper of $1\frac{1}{4}$ inch in 2 feet length of boss—the diameter of the boss equals the diameter of hole at each end, multiplied by 2. For the thickness of the roots of blades, for cast iron, multiply the diameter of screw by ·55, this tapering to $1\frac{1}{4}$ inch at the circumference, for, say 12-feet screws; the length of the screw equals one-sixth of the pitch. For brass screws the thickness of the root is found by multiplying the diameter by ·44, and all the other parts in proportion. To find the pitch of the screw for, say 11 knots per hour, 6,080 lineal feet being the knot or nautical mile, multiply 6,080 by the number of knots per hour, divide the result by the number of revolutions, multiplied by 60 minutes, and the quotient will give the pitch of the screw as it were working in a solid nut.

$$\frac{6{,}080 \times 11}{50 \times 60} = 22{\cdot}29 \text{ pitch};$$

but so much per cent. for slip must be allowed, say 14 per cent.

$$\begin{array}{r} 100 \\ 14 \\ \hline 86 \end{array} : 22{\cdot}29 : : 100 = 26 \text{ feet actual pitch.}$$

SCREW APERTURE.

To find the screw aperture for a merchant ship,

divide the diameter of screw, for say 15 feet, by 2·5, equals 6 feet long.

I have given the screw-propeller here, though not actually required at present, as it is generally the last thing that is put in hand; but should the vessel be progressing rapidly it may be required long before the engines are completed, in order to be fitted to the ship before launching.

SCREW SHAFTING AND THRUST.

The diameter of the propeller shaft should be the same diameter as the cranked shaft, namely, 12 inches. The lying shafting, divide the area of journals of the cranked shaft by 1·13, and the quotient gives the area in square inches:

$$\frac{113}{1{\cdot}13} = 100 = \text{say } 11\tfrac{1}{4} \text{ inches diameter.}$$

The most approved form of coupling is the solid disc, forged on the shaft—the thickness one-third of the diameter of shaft. A projection is formed on the face of the disc, $\frac{3}{4}$ of an inch deep, and $\frac{5}{8}$ths of the diameter, fitting into a corresponding face in the disc adjoining, the whole secured with bolts and nuts; a key is likewise sunk into one disc, and secured with screws. This key being half sunk into each disc takes the sheering strain off the bolts; the area of all the bolts $\frac{1}{6}$ of the area of shaft. The thrust of the screw is received on a series of collars, forged on the shaft, accurately turned, and

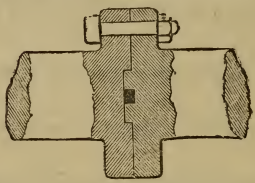
Table of the Proportions of Griffith's Screw Propeller.

Diameter of Screw.	Diameter of Boss.	Length of Boss.	Diameter of Flange of Blade.	Thickness of Flange of Blade.	Diameter of Shank of Blade.	Metal round Shank.	Metal btwn. Flange and top of Cutter.	Width of Main Cutter.	Thickness of Cutter.	Widest part of Blade above Boss.	Width of Blade at widest part.	Width at point of Pitch.	Thickness at Root.	Thickness at point of Blade.	Thickness of Feather in Boss.	Angles on Sides of Wedge Box.
ft.	ft. in.	ft. in.	ft. in.	in.	in.	in.	in.	in.	in.	in.	ft. in.	ft. in.	in.	in.	in.	degrees.
6	1 9	1 $1\frac{3}{5}$	0 $10\frac{1}{2}$	$\frac{1}{2}$	$5\frac{1}{4}$	1	$1\frac{1}{4}$	$2\frac{5}{8}$	$\frac{7}{8}$	$4\frac{1}{2}$	2 0	0 $10\frac{3}{4}$	2	$\frac{6}{16}$	$\frac{1}{2}$	$7\frac{1}{2}$
7	2 0	1 3	1 0	$\frac{5}{8}$	6	1	$1\frac{3}{4}$	3	1	$5\frac{1}{4}$	2 4	1 0	$2\frac{5}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	,,
8	2 3	1 $4\frac{7}{8}$	1 $1\frac{1}{2}$	$1\frac{1}{16}$	$6\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{7}{8}$ $\frac{1}{16}$	$3\frac{3}{8}$	$1\frac{1}{8}$	6	2 8	1 $1\frac{3}{4}$	$2\frac{5}{8}$	$\frac{7}{16}$	$\frac{11}{16}$	,,
9	2 6	1 $6\frac{1}{8}$	1 3	$\frac{3}{4}$	$7\frac{1}{2}$	$1\frac{1}{4}$	$2\frac{3}{16}$	$3\frac{3}{4}$	$1\frac{1}{4}$	$6\frac{3}{4}$	3 0	1 $3\frac{3}{4}$	3	$\frac{1}{2}$	$\frac{3}{4}$	,,
10	2 9	1 $8\frac{1}{8}$	1 $4\frac{1}{2}$	$\frac{3}{4}$ $\frac{1}{16}$	$8\frac{1}{4}$	$1\frac{3}{8}$	$2\frac{3}{8}$	$4\frac{1}{8}$	$1\frac{3}{8}$	$7\frac{1}{2}$	3 4	1 $5\frac{1}{8}$	$3\frac{1}{4}$	$\frac{1}{2}$ $\frac{1}{16}$	$\frac{3}{4}$ $\frac{1}{16}$	,,
11	3 0	1 $10\frac{1}{2}$	1 6	$\frac{7}{8}$	9	$1\frac{1}{2}$	$2\frac{5}{8}$	$4\frac{1}{2}$	$1\frac{1}{2}$	$8\frac{1}{4}$	3 8	1 7	$3\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	,,
12	3 6	2 $2\frac{1}{4}$	1 9	$1\frac{1}{16}$	$10\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{16}$	$5\frac{1}{4}$	$1\frac{3}{4}$	9	4 0	1 $8\frac{1}{2}$	4	$\frac{5}{8}$ $\frac{1}{16}$	$1\frac{1}{16}$	,,
13	3 6	2 $2\frac{1}{4}$	1 9	$1\frac{1}{16}$	$10\frac{1}{2}$	$1\frac{3}{4}$	$3\frac{1}{16}$	$5\frac{1}{4}$	$1\frac{3}{4}$	$9\frac{3}{4}$	4 4	1 $10\frac{1}{4}$	$4\frac{1}{4}$	$\frac{3}{4}$ $\frac{1}{16}$	$1\frac{1}{16}$	,,
14	4 0	2 6	2 0	$1\frac{3}{16}$	12	2	$3\frac{1}{2}$	6	2	$10\frac{1}{2}$	4 8	2 0	$4\frac{5}{8}$	$\frac{3}{4}$ $\frac{1}{16}$	$1\frac{3}{16}$	,,
15	4 0	2 6	2 0	$1\frac{3}{16}$	12	2	$3\frac{1}{2}$	6	2	$11\frac{1}{4}$	5 0	2 $1\frac{3}{4}$	5	$\frac{7}{8}$	$1\frac{3}{16}$	,,
16	4 3	2 $7\frac{1}{8}$	2 $1\frac{1}{2}$	$1\frac{1}{2}$	$12\frac{1}{4}$	$2\frac{1}{8}$	$3\frac{5}{8}$ $\frac{1}{16}$	$6\frac{3}{8}$	$2\frac{1}{8}$	12	5 4	2 $3\frac{3}{8}$	$5\frac{1}{4}$	$\frac{7}{8}$ $\frac{1}{16}$	$1\frac{1}{4}$	,,
17	4 6	2 $9\frac{1}{2}$	2 3	$1\frac{5}{8}$	$13\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{7}{8}$ $\frac{1}{16}$	$6\frac{3}{4}$	$2\frac{1}{4}$	$12\frac{3}{4}$	5 8	2 $5\frac{1}{8}$	$5\frac{5}{8}$	$\frac{7}{8}$ $\frac{1}{16}$	$1\frac{3}{8}$	,,
18	5 0	3 $0\frac{1}{2}$	2 6	$1\frac{1}{2}$	15	$2\frac{1}{2}$	$4\frac{3}{8}$	$7\frac{1}{2}$	$2\frac{1}{2}$	$13\frac{1}{2}$	6 0	2 $6\frac{1}{8}$	6	1	$1\frac{1}{2}$	,,
19	5 0	3 $0\frac{1}{2}$	2 6	$1\frac{1}{2}$	15	$2\frac{1}{2}$	$4\frac{5}{8}$	$7\frac{1}{2}$	$2\frac{1}{2}$	$14\frac{1}{4}$	6 4	2 $8\frac{1}{2}$	$6\frac{1}{4}$	$1\frac{1}{16}$	$1\frac{1}{2}$	,,
20	5 6	3 $5\frac{1}{8}$	2 9	$1\frac{5}{8}$	$16\frac{1}{4}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$8\frac{1}{8}$	$2\frac{3}{4}$	$15\frac{1}{4}$	6 8	2 $10\frac{1}{4}$	$6\frac{5}{8}$	$1\frac{1}{16}$	$1\frac{5}{8}$	,,
21	5 6	3 $5\frac{1}{8}$	2 9	$1\frac{5}{8}$	$16\frac{1}{4}$	$2\frac{3}{4}$	$4\frac{3}{4}$	$8\frac{1}{8}$	$2\frac{3}{4}$ $\frac{1}{16}$	$15\frac{3}{4}$	7 0	3 0	7	$1\frac{1}{8}$	$1\frac{5}{8}$	,,
22	6 0	3 9	3 0	$1\frac{3}{4}$	18	3	$5\frac{1}{4}$	9	3	$16\frac{1}{2}$	7 4	3 $1\frac{3}{4}$	$7\frac{1}{4}$	$1\frac{3}{16}$	$1\frac{3}{4}$ $\frac{1}{16}$	,,
23	6 0	3 9	3 0	$1\frac{3}{4}$ $\frac{1}{16}$	18	3	$5\frac{1}{4}$	9	3	$17\frac{1}{4}$	7 8	3 $3\frac{3}{8}$	$7\frac{5}{8}$	$1\frac{5}{16}$	$1\frac{3}{4}$ $\frac{1}{16}$	,,
24	6 6	4 $0\frac{5}{8}$	3 3	$1\frac{7}{8}$ $\frac{1}{16}$	$19\frac{1}{4}$	$3\frac{1}{4}$	$5\frac{5}{8}$	$9\frac{5}{8}$	$3\frac{5}{16}$	18	8 0	3 $5\frac{1}{8}$	8	$1\frac{3}{8}$	$1\frac{7}{8}$ $\frac{1}{16}$	,,

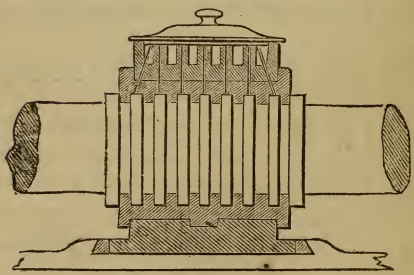
Blades of screw to curve forward half an inch to every foot diameter of screw from face to root; curve in blade to commence at centre of blade.

fitting into brass bushes in pillow-box. The combined area of the thrust surface is found by multi-

Section of Brass Bush, with Wood Bearing for Screw Shaft.



Coupling for Screw Shafting.



Thrust Block.

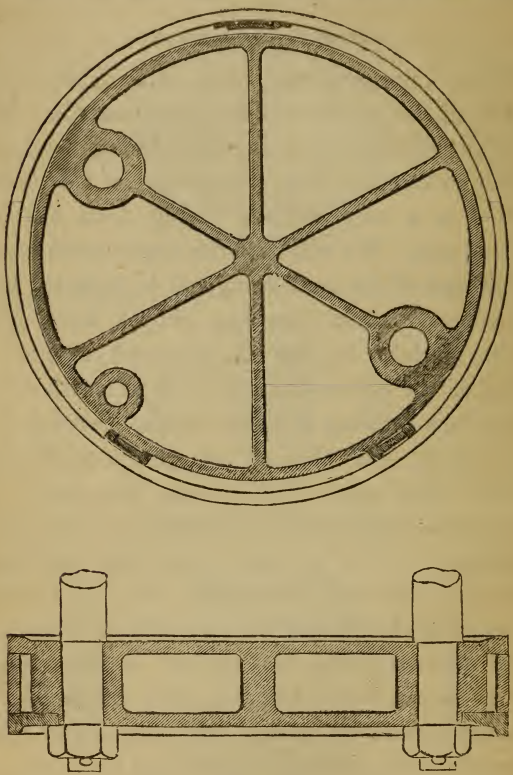
plying the horse-power by 1·25, which gives the number of square inches of thrust surface in the

whole series of collars, the length and depth of the collars being $\frac{1}{8}$ of the diameter of shaft.

PISTON ARRANGEMENTS.

Piston improvements, of all the details of the steam engine, can be reckoned by hundreds. What is to be studied in pistons, for horizontal engines, is ample surface for wear. A piston for a horizontal engine is a very different thing from that of a vertical one. We will take the single-trunk engine. The thrust of the connecting-rod is imparted to the piston and trunk, therefore should have ample surface; while in the double-trunk engine the thrust of the connecting-rod is taken on the trunks, the trunks forming a hollow beam, carrying their own weight and that of the piston, while other pistons have broad spring-rings for wear. The designers of the double trunk are so sensible of the requirements, that in some cases they use rings of the "Ramsbottom" description. Can this be excelled in simplicity? I have named one-fifth of the diameter of cylinder as the depth of piston. I have instances by me where one-fourth has been adopted as the rubbing-surface of piston, the section of piston resembling the letter T—the vertical line representing the body, and the horizontal line the rubbing surface. The packing or spring-ring should not be less than one-ninth of the diameter of cylinder, equal 7 inches broad; the junk-ring $1\frac{3}{4}$ inch thick;

and the bottom ring $1\frac{5}{8}$ inch in thickness. This will make the body of piston $10\frac{3}{8}$ inches deep. On



Piston.

the junk-ring is cast a projecting flange, $1\frac{1}{4}$ inch deep, making the junk-ring surface 3 inches deep, and the bottom of piston a projection $\frac{7}{8}$ of an inch,

making the bottom ring $2\frac{1}{2}$ inches deep—thus we have $7 + 3 + 2\frac{1}{2} = 12\frac{1}{2}$ inches rubbing surface of piston. With this arrangement the cylinder can be made a little shorter, care being taken to have the necessary clearance, namely, $\frac{3}{4}$ of an inch at each end, as likewise in the recesses formed in the end of cylinder and cover. However, the piston can be made plain at the bottom, and the junk-ring only having the projecting flange, at the same time having the bottom ring the same depth. This is obvious, as the piston has about the same rubbing-surface as the packing-ring, and has more duty to perform owing to its weight. The thickness of the spring-ring, one-fifth of its breadth, say $1\frac{1}{2}$ inch. The ring is kept up to the face of cylinder with flat springs, and sometimes with springs shaped like the letter U, recessed into the body of piston. There are two pieces of cast-iron on the under side, inserted between the spring-ring and body of piston—this tends to keep the body and ring always central; the pitch of these blocks, one-fifth of the circumference; the ends of piston $1\frac{3}{8}$ inch thick, with the necessary bosses for piston-rods, and ribs radiating from centre, holes being left in the castings so as to extract the cores; those holes are afterwards plugged up. The junk-ring bolts, $1\frac{1}{4}$ inch in diameter, simply screwed into well-tapped holes in the cast-iron. Some arrangements have wrought-iron nuts inserted in piston, or, as in the locomotive engine, brass is used.

COPPER PIPES

As supplied to Ships in the Royal Navy.

The steam-pipes, blow-off, bilge, and waste-water pipes to be not less than $\frac{1}{4}$ of an inch thick; feed-pipe, $\frac{3}{16}$ of an inch; and waste steam $\frac{1}{8}$ of an inch in thickness. The main steam, as before mentioned, is $16\frac{1}{2}$ inches in diameter. As there will be four boilers, and one stop-valve and pipe to each, the stop-valves and pipes will be one-fourth of the area of main steam-pipe, say $8\frac{1}{2}$ inches in diameter. The pipes branching off to cylinders are 14 inches in diameter; blow-off pipes on each boiler, 3 inches in diameter; bilge injection, $5\frac{1}{2}$ inches diameter; waste-water pipe, 19 inches diameter. The main feed-pipe should equal that of the pump diameter; but as it is a long pipe, 5 inches will be better: the branch pipes in the boiler, $2\frac{1}{2}$ inches, or one-fourth area of the main one; waste-steam pipe, $9\frac{3}{8}$ inches in diameter; injection pipes, $5\frac{3}{4}$ inches in diameter and $\frac{3}{16}$ of an inch thick.

Flanges for Pipes.

Diameter of Pipe. Inches.		Diameter of Flange. Inches.	Diameter of Pipe. Inches.		Diameter of Flange. Inches
$1\frac{1}{2}$	=	4	$7\frac{1}{2}$	=	11
2	=	5	8	=	$11\frac{1}{2}$
$2\frac{1}{2}$	=	$5\frac{1}{2}$	$8\frac{1}{2}$	=	12
3	=	6	9	=	$12\frac{3}{4}$
$3\frac{1}{2}$	=	$6\frac{3}{4}$	$9\frac{1}{2}$	=	$13\frac{1}{4}$
4	=	$7\frac{1}{2}$	10	=	$13\frac{3}{4}$
$4\frac{1}{2}$	=	8	$10\frac{1}{2}$	=	$14\frac{1}{4}$
5	=	$8\frac{1}{2}$	11	=	$14\frac{3}{4}$
$5\frac{1}{2}$	=	9	$11\frac{1}{2}$	=	$15\frac{1}{4}$
6	=	$9\frac{1}{2}$	12	=	$15\frac{3}{4}$
$6\frac{1}{2}$	=	10	$12\frac{1}{2}$	=	$16\frac{3}{8}$
7	=	$10\frac{1}{2}$	13	=	17

BOLTS IN CYLINDER COVER.

Supposing the pitch of bolts in cover to be 8 inches, running out 27 bolts in all, to find the area of each bolt at the bottom of the thread, multiply the area of cylinder by the steam pressure 20 lbs., divide the product by 2,240, and then by the number of bolts required, and the result will give the area of each bolt, at the bottom of the thread—

$$\frac{3{,}170 \times 20}{2{,}240} = 28{\cdot}3 \div 27 = 1{\cdot}0$$ area at bottom of thread = $1\frac{1}{8}$ diameter nearly. Adding the thread will give the full diameter of bolt: this will be sufficient guide for all other bolts subjected to like strains, the pitch of bolts usually being eight times the diameter of bolt.

HEXAGONAL (BOLTS) NUTS, HEADS, &c.

Diameter of bolts in inches ..	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$
Width of nut over angles	$\frac{7}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{7}{8}$	$\frac{7}{8}$	1	$1\frac{1}{8}$
Depth of nut	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$
Depth of head	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{1}{2}$
Number of threads to the inch	20	18	16	14	12	$11\frac{1}{2}$	11

Diameter of bolts in inches ..	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
Width of nut over angles....	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{7}{8}$	$2\frac{1}{8}$	$2\frac{3}{8}$	$2\frac{5}{8}$	$2\frac{7}{8}$
Depth of nut	$\frac{3}{4}$	$\frac{7}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$
Depth of head	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{7}{8}$	1	1	$1\frac{1}{8}$	$1\frac{1}{4}$
Number of threads to the inch	10	9	8	7	7	$6\frac{1}{2}$	6	$5\frac{1}{2}$

Diameter of bolts in inches ..	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{3}{4}$	3
Width of nut over angles....	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{3}{8}$	$4\frac{3}{4}$	$5\frac{1}{4}$
Depth of nut	$1\frac{3}{4}$	$1\frac{7}{8}$	2	$2\frac{1}{4}$	$2\frac{3}{8}$	$2\frac{3}{4}$	3
Depth of head	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{5}{8}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$
Number of threads to the inch	5	$4\frac{1}{2}$	$4\frac{1}{2}$	4	4	$3\frac{1}{2}$	$3\frac{1}{2}$

Angle of threads equals 55°.
Depth of threads equals pitch of threads.
One-sixth of depth rounded, top and bottom.
Half the number of threads per inch, when square.

LUBRICATION.

Hot bearings can always be reduced to the *minimum* by having ample surface, good material, and above all good workmanship. No one would think of sending out a very reedy-looking crank-shaft, more especially if the crank-pin surface showed black line running across it. Lubricators should not be too elaborate in design, neither too paltry; they should simply be efficient. For the lying screw shafting, the pillow blocks have large cups cast on the covers. The thrust-blocks are likewise so fitted with pipes and cotton siphons for each collar. Over the main bearings, running lengthways, a pipe is carried up, with suitable standards, easily removed, on which are attached the main oil-cups for the connecting-rods. This pipe is termed the water-lubricator, and is fitted with cocks for allowing water to run over the crank-pins and main bearings, the water flowing in from the sea by gravitation; a cock is connected to one of the Kingston valves, for shutting the water off or letting it on, as occasion may require. The screw-alley pillow blocks are likewise so fitted. The connecting-rods have lubricators fixed on at crank-pin centre, with a tongue-piece for licking off the oil from a suspended cotton siphon, as the crank revolves The main bearings and all the other parts of the machinery have loose or easily removable lubricator

cups. In parts, such as the reversing shaft, &c., some would merely drill a hole and countersink it. How much more cleanly and preferable to cast on a small cup on such parts, so that the oil can be steadily poured in without running all over the machinery. As I stated, lubricators should not be too elaborate. Some deck their engines with lubricators—providing a holiday and working suit—or otherwise the working lubricator is removed when in port, and the other substituted.

SAFETY-VALVES.

For every square foot of fire-grate area make an allowance of ·5 of a square inch. ·68 multiplied by 400, multiplied by ·5, divided by 4, equals 34 square inches for each boiler, or $6\frac{5}{8}$ inches diameter. Now, two safety-valves are better than one; some would use one-half of the area for each, but the practice is to use two valves of the combined circumference of the large one, namely, 10·4 circumference equals, say, $3\frac{5}{16}$ inches diameter for each valve. There will be eight valves, therefore $8{\cdot}6 \times 8 = 68{\cdot}8 = 9\frac{3}{8}$ inches diameter for waste-steam pipe.

The ordinary spindle-valve is used enclosed in a cast-iron chest, with cover, and expansion gland for waste-steam pipes, of copper, conveying the steam to a cast-iron box, the main steam-pipe being jointed thereto. At the bottom of the box a small pipe is

fitted, running the condensed steam that may collect into a receiving tank. The valves are loaded with the necessary weights inside of boiler, and are lifted with a short lever, with shaft supported with brackets, passing through a stuffing-box in front of boiler, to which is attached a long lever and quadrants. All the working parts inside of boiler have brass bushes.

EXPANSION-VALVES.

The expansion-valves are made of brass, and are commonly of the gridiron type, worked by an eccentric and slot link, the sliding block being movable, so as to cut off to one-half of the stroke. A good description of valve, of the equilibrium type, is simply a pipe cast with, say, five annular rings or openings, with vertical distance-pieces, and ribs, and boss, for taking valve-spindle, the inside diameter being equal to branch steam-pipe. This works in another pipe of brass, with corresponding annular spaces with the necessary lap, this outside tube being enclosed in a cast-iron box having an annular box all round, so as the steam from boiler enters at the back; this valve works best vertically. The eccentric has a throw of two inches, the end of rod being attached to a rocking lever, four inches radius. On the same spindle is attached a slotted link; the radius of link and length of the connecting-rod for valve-spindle are fixed when the

valve is full open. The link is slotted to the centre of oscillation, so as to have the annular spaces full open, thus giving no motion to the valve when required, or simply no cut-off by the expansion-valve. The throttle-valve is fitted to expansion valve-box, with spindle and stuffing-box, &c.

TURNING GEAR.

It is found necessary when in harbour to turn the engines by hand, so as to change the relative position of the working parts, and prevent furrowing, induced by the galvanic action resulting from the contact of the piston-rods and brass glands, &c. The arrangement is simply a worm, working into a wheel fitted to the end of cranked shaft, the diameter of wheel being about $3\frac{3}{4}$ of the radius of main crank, the pitch of teeth $2\frac{1}{2}$ inches. The diameter of worm equals the wheel's diameter divided by 6. The worm is thrown out of gear by suitable mechanism. Some simply key up the worm-shaft bearings, which works in suitable blocks, while others adopt an eccentric motion, similar to the back motion of a turning-lathe; there is a square formed on end of shaft to receive a ratchet brace lever, having an eye on the end, so as to secure a rope thereto; thus any number of hands can be applied, as in general the back of the engine's space is somewhat confined. The ratchet has a double pall, so as to move either way. The depth of wheel and

coupling equals the diameter of shaft. Sometimes a friction-coupling is used, so that the screw can turn round when under sail alone. The necessary grip is obtained by simply screwing the couplings together with bolts and large thumb-nuts.

SCREW-ALLEY ARRANGEMENT.

The thrust-block is separate, like any other pillow block. It is bolted down to a cast-iron plate, fitted with joggles. This plate is six times the diameter of shaft in length, well bolted down to keelson, with joggles or projections cast on the underside to prevent any end movement. The lying-shaft pillow blocks are made of cast-iron, lined with white metal. The length of the blocks one and a half times the diameter of shaft, similar to any pillow block, as for a line of shop-shafting of the same diameter. The blocks are generally bedded on hard wood.

KINGSTON VALVES

BLOW-OFF AND INJECTION COCKS.

Horse-power.	Kingston.		Blow-off Stop-cocks.		Kingston.		Injection Stop-cocks	
		Inches.		Inches.		Inches.		Inches.
60	1 off	$3\frac{1}{2}$	2 off	3	1 off	5	2 off	$3\frac{1}{2}$
80	2 ,,	3	2 ,,	3	2 ,,	5	4 ,,	$3\frac{1}{2}$
100	2 ,,	4	2 ,,	4	2 ,,	4	2 ,,	4
150	1 ,,	$3\frac{1}{2}$	2 ,,	3	2 ,,	$3\frac{1}{2}$	2 ,,	$3\frac{1}{2}$
200	4 ,,	4	4 ,,	4	4 ,,	4	4 ,,	4
300	4 ,,	4	8 ,,	3	4 ,,	5	4 ,,	5

The Kingston valves and all cocks of brass fitted to the side of the ship must have cast-iron boxes or

distance-pieces fitted to the skin of the ship, to prevent oxidation. Cocks should be done away with as much as possible, and straightway stop-valves substituted.

RULE FOR TONNAGE (O. B. M.).

This is strictly the shipbuilder's department, but will not be out of place here. Multiply the length of vessel, between perpendiculars, *minus* three-fifths of the breadth, by the square of the breadth, divided by 2, and divide the result by 94, and the quotient gives the tonnage, old builders' measurement. Supposing a vessel to be 276 feet between perpendiculars, or from the fore-part of stern to after-part of stern, and the breadth 37 feet—

$$\frac{(276 - 22{\cdot}2) \times 684{\cdot}5}{94} = 1{,}848\tfrac{1}{4} \text{ tonnage.}$$

PROPORTION OF POWER TO TONNAGE.

In the merchant service the proportion of power to tonnage is as follows in some of our best examples: —*Colombo* is about 1 to 4·8; *Himalaya*, 1 to 4·9; *Pera*, 1 to 5·8; *Simla*, 1 to 3·8; while the average from 80 to 700 horse-power gives a proportion of 1 horse-power to every 4·6 of tonnage.

MAXIMUM SPEED UNDER STEAM ALONE.

Colombo . .	12·434 knots.	Pera . . .	12·5 knots.
Himalaya .	13·9 „	Simla . . .	13.35 „

PERFORMANCE OF SCREW SHIPS.

To find the Co-efficient for Screw Ships.

When a vessel is tried at a measured mile, and the speed is so many knots per hour, the co-efficient is found thus:—multiply the cube of the speed in knots, per hour, by the midship section of the vessel, in square feet, dividing the result by the indicated horse-power, and the quotient will be the co-efficient of performance—the higher the number being the best result. Supposing the vessel went at 13·9 knots per hour, having 556 square feet of midship section, and the engines indicated 2,050 horse-power—

$$\frac{13{\cdot}9 \times 13{\cdot}9 \times 13{\cdot}9 \times 556}{2{,}050} = 728 \text{ co-efficient.}$$

To find the Speed with the Co-efficient.

Multiply the indicated horse-power the engine is intended to work at by the co-efficient for the class of vessel, dividing the result by the area of midship section in square feet, and the cube root of the quotient is an approximate of the speed the vessel will attain.

$$\frac{2{,}050 \times 728}{556} = \sqrt[3]{2{,}684} = 13{\cdot}9 \text{ knots nearly.}$$

For fourteen knots per hour, the co-efficient for ironclads, the length of the vessel being seven times its breadth, may be taken at 600 as a constant, and 500 when the vessel's length is five times its breadth.

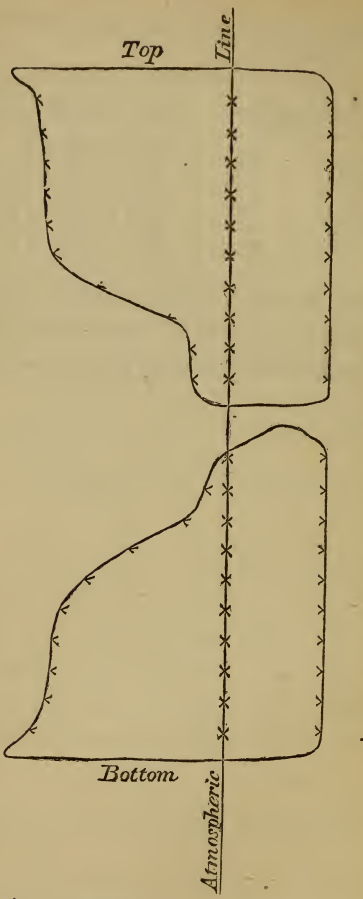
For merchant ships I will give the co-efficient of some of our vessels :—

Indicative Horse-power.	Length.	Breadth.	Midship Section.	Knots per Hour.	Co-efficient.
	Feet.	Feet.	Sq. Feet.		
Colombo, 1,463	286	36	505	12·43	= 662
Candia, 1,490.....	317	40	542	12·44	= 663
Alhambra, 454	209	27	267	10·55	= 690
Himalaya, 2,050 ..	340	44	556	13·90	= 727
Cadiz, 450	226	28	262	11·59	= 800

It will thus be seen that the longer a vessel is, in proportion to her breadth, the co-efficient will be the higher, as in the *Cadiz*, having a proportion of 8 to 1.

CARD TAKEN FROM H. M. S. S. "ICARUS."

Direct-Action Horizontal Trunk Engines of 150 nominal Horse-power. Number of revolutions per minute 91. Pressure of steam 24 lbs. Area of cylinder (bottom end) 1320·25 sq. in. Area of cylinder (top end), 1051·45 sq. in.



Area × ft. per min. × mean pressure.

$$\frac{1320{\cdot}25 \times 333 \times 24}{33{\cdot}000} = 319{\cdot}74 \text{ horse-power (bottom).}$$

$$\frac{1051{\cdot}45 \times 333 \times 25\,25}{33{\cdot}000} = 267{\cdot}9 \text{ horse-power (top).}$$

587·64 indicated horse-power.

WEIGHT OF MACHINERY, &c.
Return Connecting-rod Engines.

	80 H.P.	200 H.P.	400 H.P.	500 H.P.	600 H.P.
	Tons.	Tons.	Tons.	Tons.	Tons.
Engines	16	40	80	100	120
Boilers, &c.....	20	50	100	117	145
Water in ditto	12	30	60	75	90
Coal-boxes	3	8	10	15	15
Propeller & Shafting	6	15	35	37	47
Spare	3	7	10	12	15

CENTRE OF GRAVITY OF MACHINERY, &c.

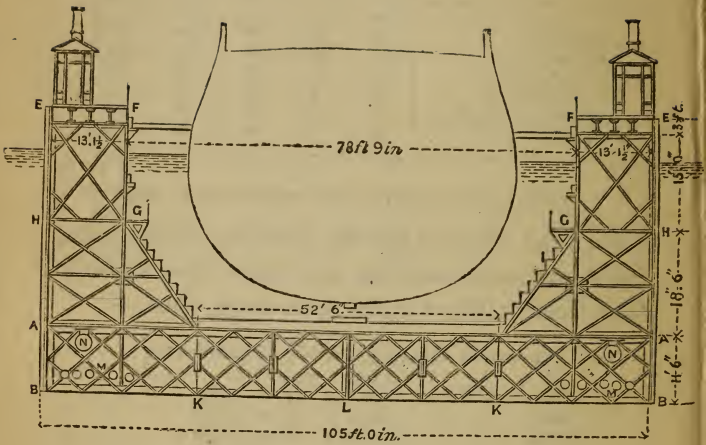
Find the centre of gravity of engine, boilers, coals, screw, and screw-shafting separately, then measure from front bulkhead in the boiler-room, thus:—

CENTRE OF GRAVITY FOR 150 HORSE-POWER.

	Feet.		Tons.	
Boilers and Water ..	10·5	×	61	= 640·5
Coals	30·0	×	125	= 3750·0
Engine	34·0	×	44	= 1496·0
			230	)5886·5(25·5
Propeller, &c.	76·0	×	11	= 836
			241	)6722·5(27·7 feet

from front bulkhead.

When the work is of a general character, the designer has often to hand over the marine branch at this stage of progress to his assistants; so it may not be out of place to communicate my experience in other branches of the profession.



FLOATING DOCK.

Those who have never been engaged on such docks can form but little idea of the amount of labour that is required in arranging such a net-work of material. When a structure of such magnitude is for the first time introduced, not merely as a floating vessel, but capable of lifting a ship entirely out of the water, having a gross weight of about 5,000 tons, more or less, some idea may be formed that it requires no ordinary care in the arrangement of all the parts to unite the whole mass in a strong and substantial manner. Having

had such work to execute in the employ of an eminent London firm, I will proceed to explain the construction of the pioneers in such novel docks.

The section adopted was of the simplest form that could be conceived. The basement, or bottom chamber, A B, was simply a rectangular pontoon, 320 feet long, 105 feet wide, and 11 feet 6 inches deep; the side walls were carried up to a height of 48 feet from the bottom of dock. On bottom of basement the walls were divided into two chambers—the middle chamber, A H, built up on basement, to a height of 18 feet 6 inches; on which was placed the floating chamber, E H, 18 feet high, for permanently supporting the dock, in case of accident to the basement or bottom chambers: for undoubtedly, were not such a precaution adopted, in the event of the chambers filling with water, the whole fabric would sink to the bottom of the sea, and there I have no doubt remain—not that it would be impossible to lift it, as nothing is now-a-days impossible, where the capital can be raised, and energy secured to execute the task. The inside of dock, or dock proper, was 78 feet 9 inches wide at top, thus leaving 13 feet 1½ inches broad for each floating chamber. The floating chambers were quite parallel, and rested on the top of middle division, but the middle chamber wall, I, had a slope towards the centre line of dock; the width of the sill, on the part upon which the vessel to be raised rested, being 52 feet 6 inches wide. I may here

state that with the whole structure complete, with vessel lifted entirely out of the water, the basement immersion was estimated to displace about 9,000 tons of sea water. So I will run into the displacement of the basement, 320 × 105 × 11·5, divided by 35, gives the amount of tons of sea water displaced equal to 11,040 tons; here we had 2,040 tons to spare: the dock of itself was calculated or estimated about 4,000 tons, but of course, as the vessel had to be lifted out of the water, it was considered best to leave a wide margin. Now I will run into the displacement of the top chamber, the combined width 26·25 × 320 × 18, divided by 35, equals 4,314 tons of sea water; thus we had 314 tons to spare. With such a base to start from we thus went to work. The centre line of the dock was the first thing to be considered; there the entire weight of the vessel was to be sustained. Therefore a centre division, L, or plating, was introduced, running the entire length of dock; as it was considered advisable to form the dock so that it should not merely be a huge pontoon for lifting a vessel, but likewise one requiring a balancing property. The dock was divided into ten water-tight compartments, with transverse bulk-heads in all the compartments carried up to within 3 feet of the top of dock on platform E E; so the basement had twenty compartments, the central division forming the "backbone" of the structure. Next comes the thickness of plat-

ing. Bottom, top, and sides of basement were $\frac{5}{8}$ of an inch thick; the sill on the space, 52 feet 6 inches wide, was flush-plated. Half up the outside walls the plating was $\frac{9}{16}$ of an inch, and all the other plates $\frac{3}{8}$ of an inch in thickness. On the top of floating chamber, four cellular divisions were formed on each side of dock 3 feet deep. The bulkheads were $\frac{3}{8}$ of an inch thick, the length of each compartment being 32 feet, having nine transverse lattice-girders in each. The top and bottom web and sides were 16 inches deep, and $\frac{5}{8}$ of an inch in thickness, with angle-iron on each side $3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$ at point, having two vertical ties on each side of middle division, or centre line of dock, formed of T iron, placed back to back, with four diagonals in each, or between verticals; between girders stiffening angle-irons $2\frac{1}{2} \times \frac{3}{8}$ at point were placed, bent down to embrace girders, and about 3 feet 6 inches apart. All the other compartments had stiffening ribs 9 inches in middle chamber, and half an inch thick, with four diagonals and one longitudinal brace to each, with angle-iron $3 \times 3 \times \frac{3}{8}$ on each side of rib, as likewise longitudinal stiffening angle-iron between, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ at point, with suitable gusset-pieces at corners. The top compartment ribs were 6 inches by $\frac{1}{2}$ inch thick, with two diagonals of angle-iron, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$, and all the necessary gusset-pieces, and angle-irons on each side for securing the sides of dock. The inside top of middle chamber was strongly

trussed lengthways, securing it to the top of basement.

The following is the calculation of weight of materials: the total plating ran out 2,249 tons; 375 tons were allowed for joints and strips, or about one-sixth more, equals 2,624 tons; the T iron, &c., ran out 950 tons, making a total of 3,574 tons. This included an extra splash plate, K, on each side, running the entire length of dock,—this plate, an after-thought, being introduced to prevent the water in basement gravitating too suddenly, in case of the dock being subjected to any sudden lurch.

The mode of plating:—instead of the plates running lengthways, as in a ship, the structure was plated transversely and vertically; all the butts were planed, and as the plates being punched with hand-labour was out of the question, three multiple punching-machines were erected, with travelling tables; the plates being accurately set, the table was moved along by hand, so the punching rapidly progressed, the pitch of the rivet-holes being $2\frac{3}{4}$ inches, and the diameter of the rivets $\frac{3}{4}$ of an inch. The dock, as it were, was merely a drawing as yet, more brain-work being required. How to sink and conveniently raise such a mass of material, sunk in the ocean to the depth of 44 feet, float in a vessel, then raise it clear out of the water, was a problem in which I had no former experience or guide to direct me. Many schemes were proposed, and,

although only acting for my employers, in my own mind I rejected them. "Here," I argued, "is a structure 320 feet long; it will never do to be running from end to end, opening and shutting the sluice-valves or valve in each compartment," so I concentrated my thoughts on the centre of length of dock. I marked out of one of the compartments about 20 feet in length, on the plan, and "here," I said, "I will take my stand, and control this 'Mammoth camel,'" (the technical term for the machine used in floating a vessel over a bar or bank). Such schemes as a long line of shafting, with pumps for each compartment, were thought of. Such did not meet my views, as out of the 20 feet I did not feel inclined to move. An idea struck me going home one evening, and rapidly as it came it was as quickly roughly sketched down on a sheet of foolscap, and presented to my employers in the morning for their approval. It was at once accepted. I merely enter into such particulars to show employers that all the thinking is not done in the drawing-office.

A leading journal of the day, commenting on such structures at the time they were merely in an embryo state, stated there was nothing new or original in the form of these docks, but that the means of sinking and raising the dock was the chief feature; that it was an important one is now sufficiently evident—other firms adopting, or nearly so, the same plan.

I placed two sluice-valves, 40 inches diameter, as near the bottom of the side of basement as convenient, with a wrought-iron barrel connection to each, on which was fitted branch pipes M, 18 inches in diameter, for receiving the sluice-valves, one to each water-tight compartment, four being placed on the side, and one on the end of barrel. No. 1 was connected to the first chamber, No. 2 to the second, and so on to the end of dock in fifth chamber, with suitable wrought-iron piping, having a bell-mouthed suction-piece of cast-iron, to within 2 inches of the bottom of dock. The wrought-iron piping being strongly riveted to bulkheads, materially stiffened the structure. Thus, on opening the large valve, the water was let into the barrel chamber, from thence into the end chamber, or any one of them separately from the others—at least, so I argued. The next process was to get it out again: it was done very simply by connecting the barrel to the pumps by means of a suction-pipe, the large sluice being shut, the engine set in motion, and so on. Of course this only provided for the basement, it being separate and distinct from the middle chambers. Again, I argued thus: "The basement is the balancing power of the dock; so, if I merely let the water in, and let it run out by gravitation, as the dock is raised, or when the water is pumped out of basement, I shall thus gain my object." So two large sluice-valves were placed higher up in the basement

connected to a wrought-iron barrel 40 inches in diameter, which was so arranged that it came exactly in the centre of one of the openings in the lattice-work. A straight pipe, N, was run fore and aft, tapering to 18 inches at end, with branch-pieces on top connected to top of basement, through which holes were cut into the middle chamber. Those pipes were also strongly riveted to bulkheads, and thus another source of stiffening was obtained. Each compartment had a man-hole door and cover, and an air-pipe of cast iron carried up to the top of dock. The engines were horizontal, placed on deck on top of dock, a wrought-iron frame or tank for fresh water forming the foundation. The cylinders were placed side by side, as close as possible, with the valves outside, worked direct from the eccentrics, the cylinders being 14 inches in diameter, with a stroke of 18 inches. There were four pumps to each engine, 20 inches in diameter, stroke 2 feet 9 inches, speed of pumps 160 feet per minute, driven by four spur-wheels, and two pinions on engine shaft. The rods for working the pumps were connected to a pin on each spur-wheel; as the rods were long, they had wrought-iron ends, and wooden distance-pieces, the wood being embraced with straps, and bolted through and through, by which means a stiff and light rod was obtained. The boilers were round, carrying a pressure of 40 lbs. per square inch, the diameter being 5 feet 6 inches, and the length 8 feet

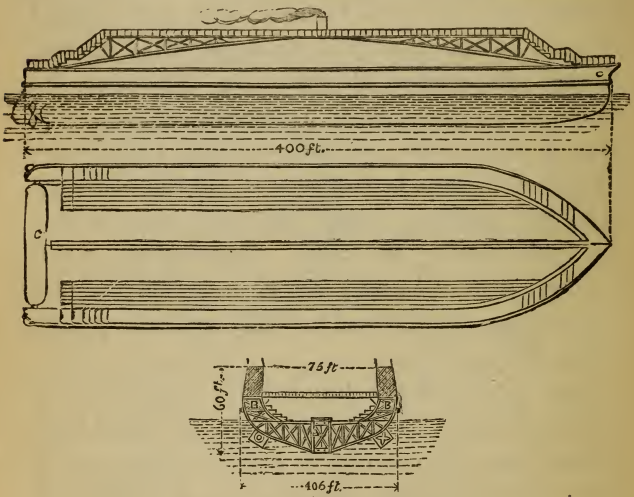
6 inches, furnaces 2 feet 9 inches diameter, with return tubes arranged round furnaces—86 tubes 2 inches diameter, 7 feet 2 inches long, and number 7 wire gauge; and six tubes at bottom of furnace, three on each side, 3 inches diameter, and 7 feet 2 inches long, number 9 wire gauge. Those large tubes were introduced to induce a downward draught, which they did effectually.

The inside of dock, or dock proper, next comes before us. The sill on bottom had balks of teak,—at bulkhead and over each lattice-frame, 2 feet deep by 18 inches broad,—carried the whole breadth of sill, or 52 feet 6 inches. On the top of those balks were wedge-pieces for shoring up the keel of vessel to be docked. The floor of the docks was covered with pitch-pine, having a slope to the side of dock for running off the water. Steps were formed on the slope of dock, of angle-iron, $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$, covered with $\frac{5}{16}$-inch plating, and 6-inch timber bolted thereto. These steps were for shoring up the sides of a vessel. At the bottom of the floating chamber a gangway, G, ran the entire length of dock, with suitable hand-rails; on the floating chamber two steps were formed of timber bolted thereto; there was a flight of steps from top of basement to top of dock, with suitable hand-rails and landings; and there was a hand-rail all round the top of dock. There were four powerful capstans on each end of dock—two on top, and two on bottom of

basement, with the necessary rollers for chains, &c. Thus I have considered all the main features of the dock in detail. To make assurance doubly sure, two of the girders were fitted up complete in the yards and loaded uniformly with 200 tons of pig-iron, and the deflection was very trifling, scarcely $\frac{1}{8}$ of an inch. Thus, the whole mass was fitted up in a temporary manner, as it had all to be taken down and shipped off to a foreign country to be again fitted up, and riveted and caulked all over. In calculating the rivets, they run out about 1,300,000 millions; 258 tons of rivets were provided;—taking the average weight of rivets to be 6 ounces, would run out about 1,493,333 millions, taking the whole mass at 250 tons, this allowing for waste. Riveting up in this country, say, one penny per rivet, would cost, for labour alone, £6,222, and the dock, as fitted up here, £23 to £24 per ton.

Some years after I had left my employers, my mind was directed to the improvements that I considered were still required in floating docks, so as to make them serviceable for sea-going purposes, and sent a drawing of my scheme to the Board of Admiralty, and leading journals of the day. Taking the freightage, labour of fitting up in a foreign country, and the unstability of a flat pontoon in a sea-way, I formed the basement ship-shaped, placed the floating chamber above, formed a bow at one end, introduced a caisson at the other end, did away with

part of the side walls, and introduced open lattice girder work instead—thus lessening the cost; placed a hollow keel on each side, and as I considered the dock should be self-propelling, the keels formed the screw-alleys for the shafting, fitted with twin-screws. The object of my arrangement was to produce a dock suitable for following a fleet in time



Floating Docks by the Author.

of war, so as to be able to lift a vessel of the *Warrior* class, for temporary repairs, without liability of tilting over, as, when the vessel rested on the dock, the dock would be sunk 20 feet, or double the distance of the one I have explained; and I am convinced, should docks be needed of the floating type, they will require to be made as I have pointed

out. I give this brief description place in "Modern Workshop Practice," so as to show young men entering the profession what will be required of them. Larger schemes are looming in the distance, and it were as easy to lift the *Great Eastern* out of the water, with such an arrangement, as the vessels these docks have now been successfully tested with.

HIGH-SPEED ENGINES.

Engines of the largest power have a speed of piston of 400 feet per minute; when we consider a piston of 2 tons moving forward and backward at this velocity without straining the ship—in fact, doing easy duty at this speed—it occurs to me that we could have much smaller engines, with a greater speed of piston, beneficially employed in the mercantile marine, as well as the Royal Navy. It is well known that some of our locomotive engines develop 1,000 indicated horse-power, which is simply due to the high speed and great steam-pressure adopted. When we compare the size of the cylinder in a locomotive with that of the marine engine it is somewhat startling; suffice, at the present, to state that the marine engine cylinders to develop 1,000 indicated horse-power are somewhat larger in diameter than the barrel of the locomotive boiler. Now, instead of two large cylinders, why should we not have six smaller ones? Say 16 inches diameter and 2 feet stroke, running at a speed of piston of 800 feet per minute with 60 lbs. steam-pressure—or, taking the same number of cylinders with the Admiralty rule for nominal horse-power, the cylinders would be

about 22½ inches diameter. Now these engines would have two hundred revolutions per minute—much too great to drive the screw-direct. We have had huge, ponderous slow-going engines, filling up the ship with their great bulk and weight, with spur-wheel and pinion driving the screw-propeller; why not have a smaller type of engine with pinion on engine-shaft and spur-wheel on the propeller-shaft, thus reducing the speed for the propeller? Some may object to this reduction, but in my opinion there is no more objection to this arrangement than in the reduction of the rolls in a sugar-mill, &c., and the advantages to be derived are immense. Engines on this principle would be much cheaper than those now in use; the cylinders and adjuncts would weigh only a few hundredweights. Instead of carrying large spare pistons weighing two tons, we could have spare cylinders and pistons fitted complete, so that in a few hours a cylinder could be replaced; in fact, six spare cylinders complete could be as easily stowed away in a ship as one large piston, and more easily handled. The crank-shaft, connecting-rods, &c., as regards weight, would be a mere bagatelle; the facilities for repairing these engines at sea or in harbour would be very great; should anything go wrong with one cylinder, lift it out and put in another; and this would be very easily accomplished, considering we are dealing with hundredweights instead of tons, as in the large engines.

These engines may be non-condensing, the waste-steam producing the blast, as likewise partially heating the feed-water. The boiler would be cylindrical; many vessels so fitted have given excellent results. The most approved design of engine may be placing the cylinder diagonally; the pinion or engine-shaft being over the spur-wheel, the cylinders would be on each side of the centre line of ship, two cylinders being connected to one crank, the shaft having three cranks would be well balanced. Horizontal arrangements may be adopted having one engine-shaft with pinion inside of spur-wheel, but for large power I do not consider over-hung spur-wheels a good arrangement. Two pinions may be adopted to the horizontal and vertical type with two engine-shafts, to a strong-framed diagonal engine seems the best arangement for the navy; these engines can be placed below the water-line.

WEIGHT OF SCREW-PROPELLERS.

Diameter.		Pitch.		Weight in Cwts.	Material.
Ft.	In.	Ft.	In.		
8	0	12	0	22	Brass.
9	6	12	0	25	Brass.
10	0	14	6	40	Brass.
10	0	15	6	44	Brass.
13	0	17	0	35 boss, 40 three blades	Brass.
14	6	17	0	72	Cast iron.
16	0	21	0	93	Brass.
16	0	23	0	95 three blades	Cast iron.
17	0	19	0	66 boss, 76 three blades	Brass.

GROSS WEIGHT OF DIRECT-ACTION SINGLE-PISTON ENGINE OF 400 HORSE-POWER.

Diameter of Cylinder, 63¼ inches. Stroke, 2 feet 9 inches.

	Tons.	cwt.	qrs.	lbs.
Pistons	4	3	0	20
Cylinders	10	4	2	20
Cylinder covers and plugs	2	3	3	2
Main frame and two outside frames	9	17	0	2
Main guide blocks	0	8	2	9
Condenser	7	12	0	21
	34	9	1	18
Brass for main connecting rods	0	2	3	13
Main pillow block, brasses, and cap	0	13	0	17
Sea cocks	0	1	2	16¼
	0	17	2	18¼
Piston-rods	0	16	3	16
Main cross-heads	0	16	3	15
Crank shaft	6	2	0	6
Propeller shafts	9	17	3	0
Main connecting-rods	1	3	2	16
Nuts for lower ends of piston-rods	0	1	1	18
Caps, straps, bolts, for main connecting-rods	0	17	0	6
Weigh-shafts	0	5	0	0
Bolts for main frame	0	0	1	27
Air-pump connecting-rods	0	14	0	0
Bolts for cylinder covers	0	1	2	23
Weigh-shaft levers	0	3	2	0
Total of Wrought iron	21	0	1	15
„ Cast iron	34	9	1	18
„ Brass	0	17	2	18¼
Total	56	7	1	23¼

N.B.—The cylinders had slide-valves complete, as likewise condensers had all complete, such as covers, &c., when weighed.

GROSS WEIGHT OF PARTS OF MARINE ENGINE,
450 Horse-power.

Diameter of Cylinder, 75 inches. Trunk, 35 inches. Stroke, 4 feet.

	Tons.	cwt.	qrs.	lbs.
4 boilers, each weighing 21 tons 15 cwt. 1 qr. 15 lbs.	87	1	2	4
2 cylinders, with pistons, covers, valves, &c.	38	8	3	20
4 wheels, each weighing 5 tons 14 cwt...	22	16	0	0
1 headstock	12	18	2	0
Shafting	22	1	0	0
1 funnel	4	0	0	0
2 connecting-rods	3	16	0	0
2 hot-wells	1	3	0	0
4 columns	3	4	0	0
2 air-pump buckets	1	14	0	0
2 pipes	1	13	0	0
	198	15	3	24

The above shows the enormous weight of vertical geared engines over that of the horizontal type. It will be seen that the condenser is not included, weighing alone, complete, 12 tons.

GROSS WEIGHT OF CAST-IRON WORK,

150 Horse-power Direct-acting Trunk Marine Engine
Cylinders, 3 ft. 5 in. diameter. Stroke, 1 ft. 10 in.

	Tons.	cwt.	qrs.	lbs.
2 cylinders	4	2	0	0
2 pistons	1	2	0	0
2 junk rings	0	6	2	14
2 spring ditto	0	4	2	18
2 trunks	0	13	2	0
2 condensers	4	1	1	0
2 bottoms for air-pump	0	4	1	14
2 glands, ditto	0	2	2	17
4 man-hole covers	0	3	1	12
1 hand-wheel	0	0	3	16
1 sector ditto	0	0	1	15
4 eccentrics	0	2	3	20
4 weigh-shaft brackets	0	2	1	4
4 caps, ditto	0	0	1	4
2 bottoms for plungers, air-pump	1	0	0	0

	Tons.	cwt.	qrs.	lbs.
2 gudgeons, ditto	0	0	2	17
8 plugs for pistons	0	0	1	18
6 covers, mud-hole doors	0	0	2	18
2 slide-valves	0	7	2	20
2 jackets for ditto	0	10	0	14
2 covers for ditto	0	8	3	4
2 guides for valve-spindle	0	0	1	20
8 furnace fronts	0	12	2	8
8 dead plates	0	9	2	8
1 distance-piece	0	0	0	14
2 eccentrics	0	1	0	10
2 bed-plates	0	0	2	1
1 bracket	0	0	0	17
2 caps for snifters	0	0	0	16
2 bracket hand-gear	0	0	3	1
4 packing-pieces	0	1	2	4
1 ring-turning gear	0	0	1	11
8 bearing bars, boiler	0	5	2	6
16 brackets for ditto	0	1	0	8
2 pump bed-plates	0	2	1	4
1 bracket reversing	0	0	0	16
2 safety-valve boxes	0	4	0	26
2 covers for ditto	0	0	2	22
1 gland for ditto	0	0	1	0
1 socket for ditto	0	2	0	20
2 plates	0	0	0	24
1 funnel ring	0	13	3	0
4 brackets	0	1	3	1
1 friction clutch	0	11	1	24
1 ditto ring	0	9	2	20
1 bracket	0	0	0	16
2 stop-valves	0	2	3	14
2 covers, ditto	0	0	3	12
14 piston plugs	0	0	2	11
1 thrust-block	0	8	1	10
1 starting platform	0	3	1	0
1 distance-piece	0	0	0	12
1 bracket, waste steam	0	2	1	14
1 bracket turning gear	0	3	1	14
2 eccentrics	0	0	3	26
1 top-step ladder	0	0	1	12
10 steps	0	1	0	23
1 block	0	1	0	0
100 plugs for tubes	0	3	0	16
16 hangers for bars	0	0	2	14
2 discharge-valve boxes	0	12	3	18
2 covers	0	1	1	12
2 glands	0	0	2	24
1 main frame	0	14	1	14

	Tons.	cwt.	qrs.	lbs.
2 outer ditto	1	0	1	4
3 caps	0	4	0	20
2 distance frames	0	1	3	18
2 ditto columns	0	1	2	22

Gross Weight of Cast-iron Work

For 2 pairs, 200 Horse-power Direct-acting Trunk Marine Engines.
Cylinders, 3 ft. 8 in. diameter. Stroke, 2 ft.

	Tons.	cwt.	qrs.	lbs.
4 cylinders	10	9	0	20
4 glands, ditto	0	6	3	20
2 starting brackets	0	0	3	8
1 two-bladed screw-propeller	1	13	3	12
1 three-bladed ditto	1	17	3	22
2 stern tubes	2	5	2	14
2 glands, ditto	0	1	3	20
8 weigh-shaft bearings	0	3	1	23
8 caps, ditto	0	0	3	12
4 reversing ditto	0	0	2	24
8 slide eccentrics	0	8	1	20
4 blow-off seats	0	4	3	5
4 cylinder covers	1	17	3	18
4 pistons	2	18	1	0
4 spring rings	0	10	0	0
4 junk ditto	0	11	0	24
4 trunks	1	10	2	0
4 brackets	0	1	1	4
2 outer bearings and caps	0	8	1	12
4 air-pump bottoms	0	3	0	20
4 pillow-blocks and caps	0	1	2	22
8 blocks for engine	0	1	0	27
4 slide-rod guides	0	1	0	0
2 sector starting gear	0	1	2	10
6 bearings for propeller shafting	0	8	2	2
6 caps for ditto	0	4	3	8
4 brackets, starting gear	0	0	2	10
2 distance-pieces	0	0	1	22
2 thrust-blocks	0	6	2	8
2 caps for ditto	0	2	0	4
2 lubricate covers, ditto	0	0	0	9
4 condensers	10	16	3	22
4 air-pump bottoms	0	10	1	8
4 glands, ditto	0	5	2	24
8 man-hole covers	0	6	3	4
2 hand-wheels	0	2	0	14
4 brackets	0	1	3	4

	Tons.	cwt.	qrs.	lbs.
2 friction cones	0	13	2	7
2 clutch discs	0	9	1	14
2 rings, ditto	0	19	1	15
4 slide-valves	1	2	0	24
4 jackets	1	7	2	0
4 covers	1	3	3	4
4 guides, valve-spindle	0	1	0	0
4 packing-blocks	0	1	0	24
18 ditto	0	1	2	26
4 eccentrics	0	2	0	4
8 dead-plates and bars	0	12	0	24
4 brackets	0	0	1	1
2 main frames	1	9	2	0
4 outer frames	2	6	2	14
6 blocks for caps	0	10	1	10
4 distance-frames	0	3	3	12
2 worms	0	1	2	24
8 back-plates	0	7	0	27
8 safety-valve boxes	0	3	0	7
8 covers, ditto	0	1	0	0
4 glands	0	1	0	16
2 bed-plates for thrust	0	9	1	11
22 holding-down plates	0	5	0	20
1 bracket	0	0	0	18
4 ditto	0	0	1	15
16 hangers	0	0	2	8
4 discharge-valve boxes	1	4	0	23
4 covers, ditto	0	3	1	8
4 glands, ditto	0	1	1	20
2 brackets	0	0	2	11
4 steps, waste steam	0	4	3	6
2 brackets, turning gear	0	5	0	4
8 safety-valve weights	0	5	2	8
288 fire-bars	3	13	2	23
4 stop-valve boxes	0	13	0	22
8 covers, ditto	0	3	0	0

The foregoing weights give the rough castings as weighed in the foundry; however, the weights are quite near enough for any calculations that may be required to be run out for the displacement or estimating.

DREDGING MACHINES.

Prime Cost of Dredge Boat.

(London made.)

	Weight of Iron, &c.	Labour.	Material and Labour.
	cwt. qrs.	£ s. d.	£ s. d.
Moulds and battens	..	10 3 7½	25 14 6
Blocks, shores, and staging	..	26 0 6	46 7 5
Frames and floors	317 0	151 2 2½	326 8 9½
Keel and hull	886 0	202 17 2½	843 2 9
Riveting hull	20 3	200 7 4½	215 18 9
Cutters and pins	11 0	13 3 0	29 3 2½
Painting	..	..	16 16 11
Shelf and large beams (wood)	(bolts) 5 3	..	165 8 4
Drilling hull	..	..	19 1 7½
Caulking ditto	..	..	49 4 10½
Cleaning ditto	..	..	3 11 11
Engine bearers	10 3	36 9 0½	43 18 3½
Rivets for hull	75 0	..	70 5 7½
Strips for ditto	23 3	..	13 13 9
Bolts and nuts for ribbands	3 3	..	8 0 1½
Rudder and gear complete	6 3	..	52 16 4½
Launch and launching	..	..	159 9 11½
Sundries—			
Nails, paint, varnish, &c.	..	..	35 5 2
			2,124 8 4½

Prime Cost of Dredger Buckets.

Number of Buckets, 51. (London made.)

	Weight.	Material.	Labour.	Total.
	cwt. qrs. lbs.	£ s. d.	£ s. d.	£ s. d.
Plating	156 0 7	105 15 1½	38 6 8	144 1 9½
Riveting	7 1 0	5 8 9	14 5 3½	19 14 0½
Chipping, &c.	..	..	18 0 9½	18 0 9½
306 links	119 2 8	85 3 10½	14 8 8½	99 12 7
204 carriers	21 3 12	14 16 11	33 2 8½	47 19 7½
83 pins	2 3 3	2 1 8	3 3 5½	5 5 1½
25 shoes	2 2 18	1 19 11	3 3 7½	5 3 6½
8 gallons of oil	..	1 4 0	..	1 4 0
		216 10 3	124 11 3	341 1 6

Cost for Labour on Marine Boilers.

(London made.)

	Angle-iron Smiths.	Platers.	Riveters.	Caulkers.	Smiths.	Boring Tube-plate.	Tubing.	Drilling.	Staying.	Doors & Hinges.	Filling & Proving.	Painting.	Weight.	H. P.
	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	Ton. cwt.	
Boiler	30 11 1½	142 9 0½	215 18 7	68 4 2½	55 3 1	21 14 5	22 19 8	23 16 0½	32 9 6	46 17 5	...	4 1 6	45 13	120
Funnel and Casing	4 13 4½	12 1 9½	9 3 4½	...	...	...	...	...	...	...	0 11 5	0 15 0	4 7	
Boiler	44 3 1	132 19 6	106 2 11½	54 16 10	43 7 9½	13 19 10	18 13 5½	25 15 5½	9 0 8	31 18 7	24 14 2½	1 5 4	32 5	260
Funnel and Casing	1 2 6	34 0 2	20 4 8½	...	1 19 0½	...	...	0 3 10	...	...	0 8 0	0 14 3½	4 19	
Boiler	49 12 5½	190 15 2	211 1 11½	50 17 6½	42 13 11½	15 5 4	24 15 0	37 0 6½	37 14 2½	56 0 11½	12 11 3½	1 10 10½	49 15	260
Funnel and Casing	4 6 0½	17 3 2½	24 1 2½	...	...	...	...	1 10 2	...	...	0 12 5	0 7 0	4 18	
Boiler	20 0 7	84 8 2	105 11 4½	34 7 6	14 3 0	9 11 7	8 13 5	17 10 9½	32 18 5	29 19 1½	3 3 1	0 16 9	24 14	150
2 Funnels & 4 Casings	1 14 11½	19 1 6	16 2 7½	...	...	...	...	...	...	...	0 6 0	0 3 0	3 10	
Boiler	21 3 10½	34 12 11	75 12 7	9 10 11	12 17 10½	4 17 9½	5 2 1	7 10 1	14 15 5	24 17 8	5 15 2½	0 17 1½	12 5	60
2 Funnels & 4 Casings	2 5 3½	8 17 2½	10 1 3	...	...	...	...	...	...	...	0 3 0	0 4 6	1 12	
Boiler	62 4 11½	234 1 10	250 3 10	70 6 9	69 15 6½	27 0 10½	31 13 0	51 6 5	67 1 6	8 7 7	19 3 1	3 11 8½	73 5	400
2 Funnels & 4 Casings	6 18 6	27 10 1	34 8 0½	...	...	...	...	0 4 0	...	...	0 18 5	0 14 5	5 17	
Boiler	33 14 9½	117 19 4½	166 12 6	43 17 3½	37 14 11½	14 5 2½	18 15 4	26 2 3	52 19 5	22 7 0	...	1 14 3½	53 4	350
Boiler	11 9 9½	80 16 5	61 8 11½	21 19 8	13 10 4½	6 3 6	6 10 3	10 18 1½	15 13 11	24 8 6½	5 5 9½	0 15 9	13 12	50
2 Funnels & 4 Casings	0 7 0	5 10 3	4 10 3	...	0 1 6	...	...	...	...	...	3 7 6	0 2 10	1 3	

Cost for Labour Marine Boilers.

Per ton (London made).

	Tons.	cwt.	qrs.	lbs.		£	s.	d.
Tubular	85	0	3	23	....	1,105	7	5
,, ...	59	9	2	22	....	790	19	7½
,, ...	16	2	0	24	....	276	3	10
,, ...	15	2	1	10	....	244	17	5½
,, ...	43	17	0	14	....	585	16	0½
,, ...	11	13	1	14	....	235	12	6
,, ...	59	0	3	20	....	806	4	6
,, ...	56	4	1	14	....	737	2	8½
Flue	9	10	1	0	....	110	4	4½
,,	7	0	0	0	....	116	16	4
	363	1	1	1		5,009	4	9½

To the averages add foreman's wages 7½ per cent. on labour.

Mud Barges.

Length, 50 feet.
Breadth, 17 feet.
Depth, 6 feet 6 inches.
Contents of hopper, 30 tons.
Weight of barge, 12½ tons.

Thickness of plates, ¼-inch.
Distance of frames, 2 feet.
Size of frames, $2\frac{1}{2} \times 2 \times \frac{3}{8}$.
Size of beams, $3 \times 2 \times \frac{1}{4}$.

Prime Cost of a Paddle Steam Vessel (Iron) of 285 tons, O. M. (London made).

	£	s.	d.
Moulds	18	3	5
Keel, stem, and stern posts	32	3	7
Laying blocks.....	5	14	10
Frames	118	14	9½
Floors	73	10	8½
Hull.....	660	7	5½
Ribbanding and shoring	64	18	10½
Bulkheads	37	19	9½
Rudder	33	1	5½
Keelson	24	8	1½
Engine and boiler bearer	73	15	7
Engine beams.....	71	6	8½
Cutters, pins, and drifts	32	7	10
Scores, ports, and hawse-holes....	8	8	10½
Stringer	14	0	8½
Trussing	18	14	10
Deck beams and carlings	12	19	0½
Carried forward.....	1,300	16	7½

	£	s.	d.
Brought forward	1,300	16	7½
Smith-work (bolts)	13	18	5¾
Paddle-box hinges.....	3	9	1
Knees to paddle beams & sponsons	33	17	1
Breast hook	7	0	7
Shoes and stays to sponsons.....	2	12	2
Pillars to beams.....	6	3	0
Chain plates	2	2	3
W.C.'s in cabins	1	0	8½
Rubbing plates	0	12	3
Knees for deckhouses	2	3	5½
Windlass.....	2	11	7
Pillar to bridge-board	0	7	7½
Stanchions to ditto	1	9	3
Handrail to ditto	0	5	7
Knees to ditto	0	7	5
Gangway ladders	4	17	6½
Awning stanchions	11	6	4
Cat-heads, &c.....	7	9	9½
Stearing gear	8	5	1
Davits	2	7	6
Deck seats	0	17	9
Rigging	1	14	8
Cook-house	13	16	1
Leeboards	23	1	9½
Flat under boiler	5	8	11
Shipwrights' work.....	1,039	1	0
Joiners' work	348	16	7
Wire-work	16	0	2¼
Painting	96	0	6
Caulkers	42	11	4
Mast-maker	35	1	6
Rigger.....	40	14	9
Sail-maker	89	10	6
Plumber	35	8	0
Carver	9	11	0
Boat.....	10	10	0
Sundries	38	19	0
Additional joiners' work	10	0	6
	3,270	7	5

Labour	£1,549	14	9½
Materials	1,720	12	7½
	3,270	7	5

DREDGERS.

ESTIMATE FOR 20 HORSE-POWER DREDGER MACHINERY.

London.

		£	s.
Cast iron	@ 16s. per cwt.	232	0
Wrought iron	@ 8d. per lb.	381	14
Top shaft	@ 30s. per cwt.	30	0
30 buckets	@ 56s.	196	0
Brass	@ 1s. per lb.	32	10
Ladder		15	0
Pins, sheaves, blocks, and chains		46	0
Turning shafts, hanging wheels on reels, making ladder and fitting up, 900 days	@ 7s.	315	0
Repairing patterns		32	16
Prime cost		1,281	0

CONTRACT PRICES, DREDGER COMPLETE.

London.

	10 H.-P.	20 H.-P.	25 H.-P.
	£	£	£
Engine	670	1,250	1,286
Machinery	1,400	1,500	1,800
Boat	1,140	1,200	1,800
Total	3,210	3,950	4,886

Steam tug, 20 horse-power, £2,000.
Barges, 50 tons, at £12 per ton, £600.

Scotland.

Offers sent in for a double dredger, of 30 horse-power, by three different firms: Boat, 90 feet long; beam, 28 feet; depth of hold, 9 feet 6 inches:—£6,000, £7,000, £8,500.

TWIN SCREW PROPULSION.

To the late George Rennie, Esq., C.E., we are indebted for the successful application of the twin system of screw propulsion, whereby the power of manœuvring and steering a vessel is far before that of the single screw; and should the rudder be carried away, vessels of any size can be steered with the twin system, independent of the

rudder altogether. A fleet of gun-boats, constructed for the Spanish Government, may truthfully be said to be the pioneers in this mode of propulsion; however, boats for river navigation had previously been fitted with twin screws, engined with the "disc," which has now been discarded for short-stroke, direct-action, single piston-rod engines. There is no difficulty in designing engines of a compact form. For driving twin screws separate and distinct from each other, the author recommends the reducing gear principle for large power—in fact, for all modes of propulsion with the screw, a system of small cylinders, with pinion on engine-shaft, and spur-wheel on the propeller-shaft, will sooner or later work out the huge, ponderous engines of the present day.

TWIN SCREW GUN BOAT

Of 20 horse-power collectively.

Length of boat, 70 ft.	Diameter of cylinders, $10\frac{1}{2}$ in.
Breadth of ditto, 11 ft.	Stroke of ditto, 8 in.
Depth of ditto, 5 ft.	Steam-ports, 7 in. $\times$ $\frac{1}{2}$ in. $\times$ 2 off.
Draught of water, 2 ft.	Exhaust ditto, 7 in. $\times$ $1\frac{1}{2}$ in.
Displacement, 27 tons.	Steam-pipes, $2\frac{5}{8}$ in.
2 screw-propellers, 2 ft. 4 in. diameter, three-bladed, 4 ft. pitch.	Exhaust ditto, $2\frac{1}{2}$.
	Diameter of shaft, $2\frac{1}{2}$.

BOILER FOR 60 lbs. STEAM.

Length of boiler, 7 ft. 6 in.	Number of tubes, 6.
Diameter of ditto, 5 ft. 6 in.	Diameter of ditto, 3 in.
Number of tubes, 88.	Length of ditto, 6 ft.
Diameter of ditto, 2 in.	Diameter of furnace, 2 ft. 9 in.
Length of ditto, 6 ft.	Fire-grate, 13·75 sq. ft.
	Heating surface, 352 sq. ft.

Weight of hull	11 tons 0 cwt.
Ditto of engine without shafts ..	0 „ 16 „
Weight of boiler	3 „ 5 „

Revolutions about 350. Speed attained, $9\frac{3}{4}$ miles per hour.

Twin Screw Gun Boat

Of 30 Horse-power collectively.

Length of boat, 90 ft.
Breadth of ditto, 14 ft.
Depth of ditto, 5 ft. 6 in.
Draught of water, 2 ft. 4 in.
2 screw-propellers, diameter, 2 ft. 10 in., pitch, 5 ft. 6 in.
Diameter of shaft, 3 in.
Ditto of piston-rod, 2 in.
Ditto of feed and bilge pumps, $1\frac{1}{4}$ in. × 10-in. stroke.
Diameter of cylinder, 12 in.
Stroke of ditto, 10 in.
Area of steam-port, 10 sq. in.
Main steam-pipes, $4\frac{1}{8}$ sq. in.
Branch ditto, $3\frac{1}{4}$ sq. in.
Main exhaust, $4\frac{1}{2}$ sq. in.
Branch ditto, $3\frac{1}{2}$ sq. in.
Steam-pipes, 7 lbs. copper.
Exhaust-pipes, 6 lbs. ditto.
Feed and bilge, 4 lbs. ditto.
Surface blow-off, 5 lbs. ditto.

Boiler for 60 lbs. Steam.

Length of boiler, 7 ft. 10 in.
Diameter of ditto, 6 ft. 6 in.
Number of tubes, 149.
Diameter of ditto, 2 in.
Two furnaces, &c., 2 ft. 3 in.

Fire-grate	20·6 sq. ft.
Tube surface	453 ,,
Furnace ditto	38·5 ,,
Ditto	15·6 ,,
Ditto	15·9 ,,
Total	522 ,,

Shell of boiler	$\frac{9}{16}$	of an inch thick.
Ends	$\frac{5}{8}$	,, ,,
Tube plates	$\frac{9}{16}$	,, ,,
Furnace	$\frac{5}{8}$	,, ,,
Other parts	$\frac{7}{16}$	,, ,,

Speed attained, 8 knots.

Gun Boat of 30 Horse-power.

Centre of Gravity fully equipped.

Measured from bow.

	Feet.		cwt.	
Anchors and capstan	6	×	14 =	84
Stoves	10	×	40 =	400
Gun	16	×	30 =	480
Ammunition	19	×	20 =	380
Crew	34	×	45 =	1,530
Galley	50	×	5 =	250
Boiler and water	55	×	108 =	5,940
Coals	59	×	180 =	10,620
Engines	67	×	21 =	1,407
Provisions and water	74	×	20 =	1,480
Crew and shafting	79	×	21 =	1,659
			504)	24,230(48

48 feet, centre of gravity of weights.
42 feet without coals.
44 feet with gun in back position.

The boats were fitted with an inclined plane, where the gun was slid down when not in fighting trim.

Tug Boat of 50 Horse-power.

Length of boat, 90 ft.
Breadth of ditto, 17 ft.
Depth of ditto, 9 ft.

Draught of Water.

When launched, 2 ft. 7 in.
Ditto fully equipped, 5 ft.

Oscillating Engine.

Diameter of cylinders, 2 ft. 7 in.
Stroke of ditto, 2 ft. 6 in.

Tubular Boiler.

Number of tubes, 183.
Length of ditto, 6 ft.
Diameter of ditto, $2\frac{3}{4}$ in.
Surface of ditto, 787 sq. ft.
Total surface, 937 sq. ft.
Total width of fire-grate, 6 ft. 6 in.
Length of ditto, 5 ft. 6 in.
Diameter of chimney, 2 ft. 6 in.
Height above grate, 32 ft.
Diameter of stays, $1\frac{1}{4}$ in.
Pressure of steam, 20 lbs.

Engine Details.

Diameter of air-pump, 1 ft. 9 in.
Stroke of ditto, 1 ft.
Diameter of feed-pump, $4\frac{1}{4}$ in.
Ditto of bilge ditto, $4\frac{1}{4}$ in.
Stroke of each, 1 ft.
Area of steam-ports, $1\frac{3}{4} \times 10$.
Ditto of exhaust ditto, 4×10.
Revolutions of engine, 38.
Diameter of branch steam-pipe, $5\frac{1}{2}$ in.

Paddle-wheels.

Diameter over floats, 12 ft. 6 in.
Length of floats, 6 ft.
Breadth of ditto, 1 ft. 4 in.
Number of floats immersed, 3.

Tug Boat of 80 Horse-power.

Length of boat, 140 ft.
Breadth of ditto, 25 ft.
Depth of ditto, 7 ft.
Draught of water, 1 ft. 10 in.

Engine, High Pressure, on Diagonal Cast-iron Frame.

Diameter of cylinder, 2 ft.
Stroke of ditto, 2 ft. 6 in.
Steam-ports, 12×2.
Exhaust ditto, 12×4.
Steam-pipes, $4\frac{3}{4}$ in.
Exhaust-pipes, $5\frac{1}{2}$ in.
Diameter of shaft, 6 in.
Ditto of piston-rod, 3 in.
Ditto of connecting-rod, $3\frac{1}{8}$ in.
Ditto of crank-pin, 4 in.

Paddle-wheel.

Diameter over floats, 11 ft. 4 in.
Length of float, 7 ft.
Breadth of ditto, 1 ft. 2 in.
Weight of machinery and boilers, 30 tons.

Speed attained, 10 miles per hour; 40 lbs. steam pressure.

Two Round Boilers.

Length, 14 ft. 1 in.
Diameter, 6 ft.
Number of tubes, 160.
Diameter of ditto, $2\frac{1}{2}$ in.
Length of ditto, 6 ft.
Two furnaces, diameter, 2 ft. 3 in.
Length of fire-grate, 5 ft. 4 in.
Fire-grate per H.-P., 59 sq. ft.
Heating surface per H.-P., 18 sq. ft.

Plates.

Body, $\frac{7}{16}$ in.
Dome top, $\frac{5}{8}$ in.
Ends, $\frac{5}{8}$ in.
Tube plate, $\frac{5}{8}$ in.
Back of furnaces, $\frac{1}{2}$ in.
Furnaces, $\frac{3}{8}$ in.

DOUBLE DREDGER OF 45 HORSE-POWER.

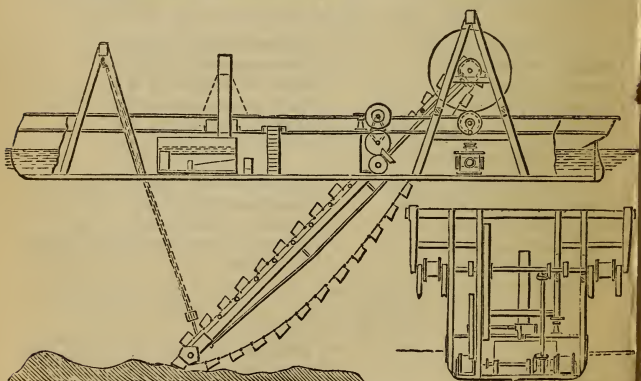
Length of boat, 110 ft.
Breadth of ditto, 26 ft.
Depth of ditto, 8 ft. 6 in.
Draught of ditto, 5 ft.
Depth to dredge, at an angle of 45°, 40 ft.
Number of buckets in each ladder, discharging 400 tons per hour with both, 32.

One Oscillating Engine.

Diameter of cylinder, 3 ft. 3 in.
Stroke of ditto, 3 ft.
Number of revolutions, 30.
Main spur-wheel, diameter, 16 ft.
Pitch of teeth, $3\frac{1}{2}$ in.
Pinion diameter, 4 ft.
Pitch of teeth, $3\frac{1}{2}$ in.
Diameter and stroke of air-pump, 25 in. × 13 in.
Depth of piston, 8 in.
Diameter of rod for ditto, $4\frac{3}{4}$ in.
Exhaust-pipe, 9 in.
Diameter of crank-shaft, $8\frac{1}{4}$ in.
Ditto of tumbler-shaft, $12\frac{1}{2}$ in.
Revolution of hoisting gear per minute, 6·8.
Diameter of drums, 3 ft.
Revolution of advancing gear, 1·7.
Diameter of surging heads, 1 ft. 9 in.
Ladder to lift 40 feet in four minutes, with six sheave blocks.

Boiler.

Length, 15 ft. 3 in.
Breadth, 11 ft. 6 in.
Depth, 6 ft.
Number of tubes, 18.
Length of ditto, 12 ft.
Diameter of ditto, 8 in.
Heating surface per H.-P., 14 sq. ft.



Double Dredger of 45 Horse-power.

This was a very simple arrangement of dredger, the pinion on engine-shaft, gearing with spur-wheel on tumbler-shaft overhead. The hoisting gear was

placed between engine and boiler, the shaft carrying hoisting drum of large diameter, fitted with a friction cone for throwing out; the shaft was driven by gear and diagonal shafts from tumbler-shaft overhead.

WEIGHT OF DOUBLE DREDGER--45 HORSE-POWER.

Length of boat, 95 ft.
Breadth of ditto, 22 ft.
Draught of ditto, 5 ft. $4\frac{1}{2}$ in.
Depth, 8 ft. 6 in.

This boat was too narrow in the beam: 26 feet would be better.

	Tons.	cwt.
Hull	99	0
Machinery and boiler	111	13
Water in boiler	11	0
Coals	15	0
Sundries	12	1
Total	248	14

DREDGER OF 25 HORSE-POWER.

Engines, 14 tons.
Boiler and bars, 8 tons 14 cwt.
Machinery, 22 tons 15 cwt.

Oscillating Engine.

Diameter of cylinder, 2 ft. 7 in.
Stroke of ditto, 2 ft. 6 in.
Diameter of air-pump, 1 ft. $6\frac{1}{2}$ in.
Stroke of ditto, 10 in.
Diameter of engine-shaft, 6 in.
Length of ladder, 53 ft.
Number of buckets, 25.
Depth to dredge, 24 ft.

Bevel Gearing.

Large wheel on tumbler-shaft, 8 ft. 4 in. diameter, 9 in. broad, $3\frac{3}{8}$ in. pitch.
Pinion, 3 ft. 2 in. $\times$ 9 in. $\times$ $3\frac{3}{8}$ in. pitch.
Friction wheel on engine shaft, 3 ft. $2\frac{1}{2}$ in. $\times$ $7\frac{3}{4}$ in. $\times$ $3\frac{3}{8}$ in. pitch.
Diameter, $7\frac{3}{4}$ in. broad, $3\frac{3}{8}$ in. pitch.
Wheel on vertical shaft, 3 ft. $10\frac{1}{2}$ in.
Diameter, $7\frac{3}{4}$ in. broad, $3\frac{3}{8}$ in. pitch.
Pinion on vertical shaft, 1 ft. 8 in. $\times$ $4\frac{1}{2}$ $\times$ 2.
Wheel for ditto, advancing gear, 3 ft. 4 in. $\times$ $4\frac{1}{2}$ $\times$ 2.
Advancing gear travels 9·5 ft. per minute.

Boiler.

Length, 14 ft.
Breadth, 7 ft. 6 in.
Height, 6 ft. 4. in.
Number, 1.
Fire-grate, 2 ft. 9 in. $\times$ 6 ft. 6 in.
Number of tubes, 12.
Diameter of ditto, 8 in.
Heating surface, 382 sq. ft. = 15 ft. per H.-P.

SCREW STEAM SHIP.

	Ft.	in.
Length of deck inside of stem and stern post	186	0
Load line	184	6
Depth moulded	17	1
Breadth	26	0
Depth under side of deck to ditto keel	18	9

Scale of Tonnage.

	Ft.	in.	Tons.
Draught when launched.....	7	7 =	374
,, ,, ...	9	3 =	540
,, ,, ...	11	0 =	690
,, ,, ...	12	7 =	870
,, ,, ...	14	6 =	1,050

SCREW STEAM SHIP.

	Ft.	in.
Length of keel and fire-rake	199	6
Breadth	27	6
Depth under side of deck to ditto keel	18	6

Scale of Tonnage.

	Ft.	in.	Tons.
Draught when launched	6	7 =	320
Ditto with machinery, water, and vessel complete	8	6 =	495
Ditto with 250 tons of coal	11	0 =	745
Ditto with 150 tons of cargo	12	4 =	895

PADDLE STEAMER.

	Ft.	in.
Length of keel and fire-rake	242	6
Breadth	27	6
Depth from deck	16	0

Scale of Tonnage.

	Ft.	in.	Tons.
Draught when launched	4	0 =	410
Ditto with machinery and water	7	0 =	783
Ditto with 36 tons of coal	7	3 =	819
Ditto with 250 tons of cargo	9	0 =	1,079

WAR VESSELS.

WEIGHT OF TWIN SCREW VESSEL.

Length.....	200 feet.
Breadth	33 ,,
Depth moulded	20 ,,
Draught of water	14 to 15 ,,

This vessel was armour-clad, having 6-inch plates over vital parts, and 6 inches in thickness; in a fixed turret carrying two 300-pounders.

	Tons.
Iron hull, and wood works	558
Battery complete with armour and backing	110
Armour on ship	330
Backing	63
Accessories and outfit	80
Engines	273
Coals	210
Water, stores, men, and effects	60
Guns and ammunition	90
Displacement	1,774

The following tabulated statement gives the weight of ironclads in the Royal Navy—of two classes, namely, long *versus* short ships:—

	Minotaur Type (long ships).	Bellerophon Type (short ships).
Length	510 feet	380 feet.
Breadth	75 „	71 „
Tonnage	13,770 tons	8,620 tons.
Nominal horse-power	1,080 H.P.	1,080 H.P.
Indicated ditto	7,560 „	7,560 „
Weights.		
Hull	7,100 tons	4,460 tons.
Armour and backing	5,190 „	3,630 „
Engine and coals	2,160 „	2,160 „
Stores	1,000 „	700 „
Displacement	15,450 „	10,950 „

Taking the average cost per ton for ironclad ships at £55 per ton of tonnage, the saving in the *Bellerophon* type would be £283,250. It is considered that ships of the *Bellerophon* type would cost less for maintenance and repairs, and would be handier in action.—C. C., R.N.

TENDERS SENT TO THE ADMIRALTY FOR COMPOSITE GUN BOATS.

464 Tons (O. B. M.).

Length, 155 ft.; breadth of beam, 25 ft.; depth, 10 ft. 9 in. The prices ranged from £20 to £37 per ton of tonnage. Taking the average of twenty competitions, £30 per ton of tonnage.

CENTRE OF GRAVITY OF VESSELS.

The position of the centre of gravity in a vertical line is the most important point to determine, more especially with ironclad vessels. I will take an example, namely, the twin-screw armour-clad war-vessel in the preceding page. Divide the vessel longitudinally into say five equal parts, A B C D E, and the mean centre of gravity of each portion found, below the load water-line, namely, 15 feet 3 inches above lower part of keel, taking the weight of the main parts, such as plating, longitudinal, and transverse frames, beams, deck plating, bulkheads, stringes, &c.; and then the miscellaneous parts of the structure, as the flat and vertical keels, stern-post, steam engine and boiler bearers, shaft passages, bulkheads of shot and chain lockers, magazine, and all ship and joiners' work, rudder, &c. :—

	Tons.		Feet.		Moments.
A	51·01	×	1·95	=	99·469
B	99·45	×	4·56	=	453·492
C	93·54	×	5·32	=	497·632
D	99·53	×	4·35	=	432·955
E	60·38	×	5·53	=	213·141
Miscellaneous	157·23	×	4·48	=	704·793
	561·14				)2401·482(= 4.279 ft. below water line.

The battery is taken separately, with bearers, iron deck frames, plating, port cills, girders, wood deck, armour plates, and wood backing—

Total Weight.		Feet above.		Moments.
115·15	×	8·426	=	970·253.

The accessories and outfit, including capstans, bitts, stoppers, galley, and cooking apparatus, black-

smiths' work, pumps, wheels, paint, anchors, chain cables, masts, sails, &c.; total weight—

Tons.		Feet.		Moments.
60	×	3·138	=	118·28

The armour-plating and backing is taken in three longitudinal strakes; a disposition of butts should be got out, and the common centre of gravity of the whole strake found, as follows :—

Armour Plates.				Backing.		
Strakes.	lbs.	Moments above.	Moments below.	Cubic Feet.	Above.	Below,
Upper	110,408	404787·9	...	443·95	1628·277	
Middle	137,708	99725·8	...	465·98	350·718	
Lower	98,315	5362·5	189459·2	446·56	23·892	846·243
2240)	346,431	509876·2	189459·2	1356·49	2002·887	
Tons...	154·65	189459·2	...	...	846·243	
	2	320417·0	...	1356·5)	1156·644	
Tons...	309·30	·9249 ft.	{ above L. W. L }	52 lb.	·852 ft.	{ above L. W. L.
Bolts...	31·1		2240)	70538·0		
	340·4			31 9 3 6 2		
Tons...	...	...	...	62 19 2 12		

The position of the centre of gravity of the whole hull will thus be found :—

	Tons.		Feet.		Moments above.	Moments below.
Iron and wood in hull	561·23	×	4·279	=		2401·5031
Armour and bolts....	340·4	×	·9249	=	314·8359	
Backing and bolts....	62·72	×	·825	=	51·7440	
Battery, including armour and backing..	115·15	×	8·426	=	970·2539	
Accessories and outfit	60·	×	3·138	=	188·2800	
	1139·50				1525·1138	2401·5031
						1525·1138
					1139·70)	876·3893
						·768

equal 9¼ inches below load water-line.

The position of centre of gravity of engines, boilers, water, propeller, &c., was found to be 6·3 feet below load water-line; thus we have:—

	Feet.
Centre of gravity of whole hull below load water-line, 1139·70 × ·7689	= 876·3893
Centre of gravity of engine, boilers, water, &c., below load water-line, 273 × 6·3	= 1719·9000
	2596·2893
Two 30-pounders, slides, races, &c., above load water-line, 42 × 6·914	= 290·4000
	1454·7)2305·8893
Below water-line	1·585

The draught of water corresponding to these weights is 13 feet 1½ inches:—

Displacement corresponding to this draught	1454·7	tons.
Centre of buoyancy below this 13 ft. 1½ in. water-line	5·175	feet.
Metacentre above centre of buoyancy	7·800	„
Centre of gravity below load water-line	1·585	„
Centre of gravity above ditto	·542	„
Distance between metacentre and centre of gravity	2·083	„

According to the above calculations, the moment for comparative stability is equal to—

$$1454{\cdot}7 \times 2{\cdot}083 = 3030{\cdot}14.$$

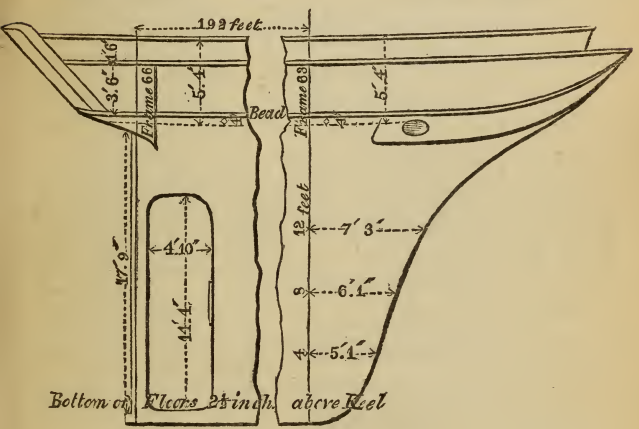
A small amount of sails was required; the moment of sails about centre of lateral resistance is 208·231; and for moment of stability for comparative stiffness under sail, displacement × G M = $\frac{3030140}{208231}$ = ·01455, with the vessel light; the 300 tons weight of stores to be added would bring the centre of gravity lower down.

The importance of such calculations cannot be disputed, and this vessel may be considered a good example of her class.

IRON SCREW STEAM SHIP.

Scale of Tonnage.

	Ft.	in.	Tons.
When launched	6	$7\frac{1}{2}$	= 320
With machinery, water, and vessel complete	8	$6\frac{1}{2}$	= 495
252 tons of coal	11	0	= 747
150 tons of cargo	12	$4\frac{1}{2}$	= 897



Iron Screw Steam Ship.

Distance between top of poop deck, beams, and top of cabin floor beam, at ship's side, 8 feet 2 inches; distance between top of main deck beams and top twixt deck beams at ship's side, 8 feet; rise of floors in half beam 3 feet, rise of main deck 9 inches, rise of poop deck 10 inches.

Distance between centres of frames throughout vessel, 18 inches; main deck beams are 4 inches below bottom of gunwale, making the depth moulded 17 feet 6 inches. Poop deck same height as main rail, commencing at 27 frame; all frames at poop to run up to the main rail, every alternate frame commencing at poop to run up to main rail, the intermediate ones to run up to bead, that is 4 inches above main deck beams; every alternate frame, for top-gallant forecastle, to run up to top-gallant rail, commencing at 52 frame.

OFFSETS.

Fore Body.

Distance between Offsets.		Frames.	2 W.L.	4 W.L.	6 W.L.	8 W.L.	10 W.L.	12 W.L.	14 W.L.	16 W.L.	Gunwale.	2 Feet above Gunwale.	Main Rail.	gallant Rail.	Depth Moulded on Bead.
ft.	in.		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
		1	8 3½	11 3½	12 8	13 4½	13 8½	13 9	13 13	13 6	13 3¼	12 11⅞	12 9½	12 6½	17 10⅞
16	6	12	8 9¼	10 10⅝	12 4⅜	13 1½	13 6	13 7	13 7	13 4⅞	12 2¼	12 0	12 3½	12 5⅛	17 11
15	0	22	6 3⅜	9 7	11 6	12 6½	13 1⅝	13 3	13 3	13 2	12 1¼	11 10½	11 8½	11 11⅝	18 1
13	6	31	4 4	7 6¼	9 11¼	11 5	12 3	12 8	12 10	12 9⅝	12 2⅝	12 0	12 4⅝	12 5⅛	18 3⅝
12	0	39	2 5½	4 11¼	7 4¾	9 5⅝	10 2⅝	11 1⅝	12 1⅝	12 3⅛	12 2⅝	12 0	12 4⅝	12 5⅛	18 5
10	6	46	1 2	2 6¼	4 4¾	6 7	8 0⅝	10 2⅛	11 1⅝	11 7⅛	11 9	11 10	11 8½	11 11⅝	18 8
9	0	52	0 6½	1 0¾	1 10½	3 3	5 5	7 10	9 7⅝	10 8½	11 3⅝	11 5⅝	11 0	11 8½	18 10⅞
7	6	57	0 2⅝	0 4¾	0 6⅝	0 11⅝	1 11⅝	4 2	7 3	9 4½	10 2⅝	10 4⅝	10 6½	10 8½	19 0
6	0	61	0 2	0 2⅝	0 2⅝	0 2⅝	0 3⅛	0 7⅝	9	7 1⅝	8 10	8 10	8 10	9	19 1
4	6	64	..	..	..	..	..	..	0 2¼	1 3⅞	3 9	4 10	4 10	4 10	19 2⅛
3	0	66	..	..	..	..	..	..	..	..	3 9	3 9¼	3 9	3 9	19 3⅜

BUTTOCK LINES.

3 Feet.		6 Feet.		9 Feet.	
ft.	in.	ft.	in.	ft.	in.
0	$7\frac{3}{4}$	1	$3\frac{1}{2}$	2	$3\frac{5}{8}$
0	$7\frac{7}{8}$	1	$4\frac{3}{4}$	2	7
0	$9\frac{1}{2}$	1	$10\frac{1}{2}$	3	6
1	$3\frac{5}{8}$	2	$11\frac{1}{2}$	5	$1\frac{3}{4}$
2	$5\frac{1}{4}$	4	$10\frac{1}{2}$	7	6
4	7	7	$5\frac{3}{4}$	10	$4\frac{1}{8}$
7	$8\frac{7}{8}$	10	$5\frac{1}{4}$	13	$2\frac{3}{4}$
11	$1\frac{5}{8}$	13	2	15	7
14	$1\frac{5}{8}$	15	5	17	$3\frac{5}{8}$
16	$4\frac{5}{8}$	17	$1\frac{1}{2}$	18	$4\frac{7}{8}$
17	$9\frac{3}{4}$	18	3	19	$0\frac{1}{4}$

Buttock Lines.

3 Feet.		6 Feet.		9 Feet.	
ft.	in.	ft.	in.	ft.	in.
0	$7\frac{3}{4}$	1	$3\frac{1}{2}$	2	$3\frac{5}{8}$
0	$8\frac{1}{8}$	1	$5\frac{1}{4}$	2	$7\frac{1}{4}$
0	$9\frac{5}{8}$	1	$9\frac{3}{4}$	3	6
1	2	2	9	5	$4\frac{5}{8}$
1	$11\frac{1}{2}$	4	$8\frac{1}{4}$	8	10
3	6	7	$10\frac{1}{2}$	13	$9\frac{1}{2}$
6	2	12	$5\frac{3}{4}$	18	$8\frac{1}{4}$
10	4	17	2	22	$10\frac{1}{2}$
15	$0\frac{1}{2}$	21	$2\frac{1}{4}$		
19	0				
21	$8\frac{1}{2}$				

Offsets.

After Body.

Distance between Offsets.		Frames.	2 W. L.	4 W. L.	6 W. L.	8 W. L.	10 W. L.	12 W. L.	14 W. L.	16 W. L.	Gunwale.	Main Rail.	Top-gallant Rail.	Depth Moulded on Bead.
ft.	in.		ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
		1	8 $3\frac{5}{8}$	11 $3\frac{1}{16}$	12 8	13 $4\frac{1}{16}$	13 $8\frac{1}{4}$	13 9	13 $8\frac{1}{16}$	13 6	13 $3\frac{1}{4}$	12 $9\frac{3}{8}$	12 6	17 $10\frac{1}{16}$
16	6	12	7 $9\frac{1}{2}$	10 $0\frac{1}{16}$	12 $4\frac{3}{16}$	13 $2\frac{1}{16}$	13 $7\frac{1}{16}$	13 $8\frac{1}{4}$	13 7	13 $5\frac{1}{16}$	13 $2\frac{1}{16}$	12 9	12 $6\frac{1}{4}$	17 $10\frac{1}{16}$
15	0	22	6 6	9 $7\frac{3}{16}$	11 $4\frac{3}{16}$	13 $5\frac{1}{16}$	13 $8\frac{1}{16}$	13 $8\frac{1}{4}$	13 $3\frac{5}{16}$	13 $2\frac{1}{16}$	13 $0\frac{1}{16}$	12 8	12 5	17 $10\frac{1}{16}$
13	6	31	4 $8\frac{3}{4}$	7 7	9 $5\frac{3}{16}$	10 $9\frac{1}{16}$	11 $8\frac{1}{16}$	12 $8\frac{1}{4}$	12 $6\frac{1}{16}$	12 $3\frac{1}{16}$	12 $0\frac{1}{16}$	11 $8\frac{5}{16}$	11 $3\frac{5}{16}$	18 0
12	0	39	3 $0\frac{1}{4}$	5 4	7 $1\frac{3}{16}$	8 $6\frac{1}{16}$	9 $7\frac{1}{16}$	10 $8\frac{1}{4}$	11 $7\frac{1}{16}$	11 $4\frac{1}{16}$	11 $1\frac{1}{16}$	10 $7\frac{1}{16}$	10 $2\frac{1}{16}$	18 $1\frac{3}{16}$
10	6	46	1 $10\frac{1}{4}$	3 5	4 $9\frac{1}{16}$	6 $0\frac{1}{16}$	7 $2\frac{1}{16}$	8 $2\frac{1}{4}$	9 $1\frac{1}{16}$	9 $10\frac{1}{16}$	10 $7\frac{1}{16}$	11 $4\frac{1}{16}$	11 $1\frac{1}{16}$	18 3
9	0	52	1 1	2 $0\frac{1}{8}$	2 $11\frac{1}{16}$	3 $10\frac{1}{16}$	4 $10\frac{1}{16}$	5 $9\frac{1}{16}$	6 9	7 8	8 $10\frac{1}{2}$	10 6	10 $9\frac{1}{2}$	18 5
7	6	57	0 $6\frac{3}{8}$	1 0	1 $6\frac{1}{16}$	2 2	2 $10\frac{1}{16}$	3 7	4 $5\frac{1}{16}$	5 5	6 9	8 9	9 9	18 7
6	0	61	0 3	0 $5\frac{1}{2}$	0 $8\frac{1}{16}$	1 $0\frac{1}{16}$	1 $5\frac{1}{4}$	1 $11\frac{1}{16}$	2 7	3 $4\frac{1}{16}$	4 8	6 $8\frac{3}{4}$	7 3	18 9
4	6	64	0 $1\frac{3}{16}$	0 2	0 3	0 4	0 7	0 $10\frac{1}{16}$	1 $3\frac{3}{4}$	2 $11\frac{3}{16}$	4 9	5 $3\frac{3}{16}$	5 3	18 $10\frac{1}{4}$
3	0	66	..	..	0 $1\frac{1}{2}$	0 2	0 $2\frac{1}{4}$	0 $4\frac{1}{4}$	0 $7\frac{1}{16}$	1 0	1 $10\frac{1}{2}$	3 $4\frac{1}{2}$	3 9	18 $11\frac{3}{4}$

Displacement of a River Steamer (Paddle-wheel).

Stirling's Rule.

Length, 160 ft.; breadth of beam, 18 ft.; depth moulded, 8 ft. 6 in.
Distance between ordinates, 13·33.

Multipliers.	Ordinates.	Keel.	1st. W. L.	2nd. W. L.	3rd. W. L.	4th. W. L.							Volume for displacement.	Centre of displacement.
		1	4	2	4	1								
1	1	·1	·1	·1	·1	·2	·2	·2	·2					
		·1	·4	·2	·8	·2						=	1·7 × 1 =	1·7 ×
4	2	·1	·4	1·1	4·4	1·5	6·0	2·0	8·0	2·2	8·8			
		·1	4·4		3·0		8·0		2·2			=	17·7 × 4 =	70·8 × 1 = 70·8
2	3	·1	·2	2·7	5·4	3·5	7·0	4·1	8·2	4·5	9·0			
		·1	10	8		7·0		16·4		4·5		=	38·8 × 2 =	77·6 × 2 = 155·2
4	4	·1	·4	4·4	17·6	5·4	21·6	6·0	24·0	6·5	26·0			
		·1	17·6		10·8		24·0		6·5			=	59·0 × 4 =	236·0 × 3 = 708·0
2	5	·1	·2	6·1	12·2	7·0	14·0	7·6	15·2	7·9	15·8			
		·1	24·4		14·0		30·4		7·9			=	76·8 × 2 =	153·6 × 4 = 614·4
4	6	·1	·4	6·4	25·6	7·7	30·8	8·3	33·2	8·5	34·0			
		·1	25·6		15·4		33·2		8·5			=	82·8 × 4 =	331·2 × 5 = 1656·0
2	7	·1	·2	7·1	14·2	8·0	16·0	8·5	17·0	8·7	17·4			
		·1	28·4		16·0		34·0		8·7			=	87·2 × 2 =	174·4 × 6 = 1046·4
4	8	·1	·4	6·8	27·2	17·7	30·8	8·3	33·2	8·6	34·4			
		·1	27·2		15·4		33·2		8·6			=	84·5 × 4 =	338·0 × 7 = 2366·0
2	9	·1	·2	5·8	11·6	6·9	13·8	7·7	15·4	8·1	16·2			
		·1	23·2		13·8		30·8		8·1			=	76·0 × 2 =	152·0 × 8 = 1216·0
4	10	·1	·4	4·3	17·2	5·5	22·0	6·5	26·0	7·2	28·8			
		·1	17·2		11·0		26·0		7·2			=	61·5 × 4 =	246·0 × 9 = 2214·0
2	11	·1	·2	2·6	5·2	3·6	7.2	4·6	9·2	5·5	11·0			
		·1	10·4		7·2		18·4		5·5			=	41·6 × 2 =	83·2 × 10 = 832·0
4	12	·1	·4	1·1	4·4	1·6	6·4	2·3	9·2	3·0	12·0			
		·1	4·4		3·2		9·2		3·0			=	19·9 × 4 =	79·6 × 11 = 875·6
1	13	·1	·1	·1	·1	·1	·2	·2	·2	·2				
		·1	·4		·2		·8		·2			=	1·7 × 1 =	1·7 × 12 = 20·4
		3·6		145·2		175·8		199·0		213·8			1945·8	11774·8
		1		4		2		4		1				
		3·6		580·8		351·6		796·0		213·8				
		580·8												
		351·6												
		796·0												
		213·8												
		1945·8												

$$\frac{649{\cdot}2 \times 13{\cdot}33}{3} = 2884{\cdot}6 \div 35 = 82{\cdot}4 \times 2 = 164{\cdot}8 \text{ tons.}$$

$$\frac{11774 \times 13{\cdot}33}{1945{\cdot}8} = 80{\cdot}6 \text{ feet centre of displacement from after end of stern-post.}$$

SHIP BUILDING ON THE "CLYDE" (Piece Work).

For Ships of 1000 Tons (O. B. M).

Shell, and mast plates, average 10 feet × 3 feet—all the work fitted up for riveting.

	£	s.	d.
Frames $4\frac{1}{2}$ in. × 3 in. × $\frac{1}{2}$ in., with floors 20 in. × $\frac{1}{2}$ in. at middle, tapering up to bilge with reverse bars, also main and lower deck beams, 8 in. × $\frac{1}{2}$ in. bulb iron, with two angle irons, $2\frac{1}{2}$ in. × $2\frac{1}{2}$ in. × $\frac{5}{16}$ in., all made ready for riveting, per frame	2	0	0
Hull plating, per plate	0	8	0
Keel plates, or garboard strake, per plate	0	16	0
Butt strips, per plate	0	0	5
Bulkhead plates, with stiffening bars	0	8	0
Mid-deck stringers, 12 in. × 30 in. × $\frac{1}{2}$ in. per plate	0	6	9
Coal bunkers and bars, varies according to form	0	6	0
	0	7	6
Moulding iron, $3\frac{1}{2}$ in. × $1\frac{1}{2}$ in., per foot	0	0	3
Screw alley, or tunnel	30	0	0
Keelsons, 5 in. × 4 in. × $\frac{1}{2}$ in., per double foot	0	0	7
$\frac{5}{8}$ inch rivets, per 100	0	6	3
$\frac{3}{4}$ " "	0	7	6
$\frac{7}{8}$ " "	0	9	0
Mast plates	0	7	6
Do. do., with three-angle iron, 3 in. × 3 in. inside, including strip	0	9	6
Steel masts, jump jointed, with strips	0	10	0
Side lights, according to size, cutting, and riveting	0	3	0
	0	5	0
Caulking, the edges being planed	35	0	0

Bulkheads chipping and caulking frame, 6d. per yard; plates, 3d. per yard; drilling holes averages 1s. per dozen.

The method of bending the frames to a drawing inscribed on a large black board, as adopted by the Clyde shipbuilders, is far before the plan of forming the frames to a wooden template. With the former the top ends of the timbers or frames can be cut exactly as per drawing, while with the templating system there is some risk; moreover, the expenses of making templates is considerable, and altogether the process is rude.

SHIP BUILDING ON THE "THAMES" (Piece Work).

Blackwall.

Outside Riveting, per Yard.

Seams.			Timbers.			Keels.			Inside Work.		
in.	per yard. s.	d.	in.	per yard. s.	d.	in.	per yard. s.	d.	in.	per yard. s.	d.
$\frac{1}{4}$	0	7				Inner $1\frac{1}{4}$	6	0	$\frac{7}{16}$	0	6
$\frac{7}{16}$	0	8	$\frac{7}{16}$	0	11	Outer $1\frac{1}{4}$	7	0	$\frac{1}{2}$	0	8
$\frac{1}{2}$	0	9	$\frac{1}{2}$	1	1	,, $1\frac{1}{8}$	4	6	$\frac{5}{8}$	0	10
$\frac{5}{8}$	0	11	$\frac{5}{8}$	1	3	,, 1	3	6	$\frac{3}{4}$	1	0
$\frac{3}{4}$	1	3	$\frac{3}{4}$	1	10	,, $\frac{7}{8}$	2	4	$\frac{7}{8}$	1	1
$\frac{7}{8}$	1	4	$\frac{7}{8}$	2	4	,, $\frac{3}{4}$	1	10			
						,, $\frac{5}{8}$	1	6			

Angular tanks, including caulking, 6d. per yard.
Square ,, ,, $4\frac{1}{2}$d. ,,

Drilling Solids.

Diameter of holes	2 in.	$1\frac{3}{4}$ in.	$1\frac{1}{2}$ in.	$1\frac{1}{4}$ in.	1 in.	$\frac{7}{8}$ or $\frac{3}{4}$ in.
Price per inch ..	6d.	5d.	$4\frac{1}{2}$d.	$3\frac{1}{2}$d.	2d.	$1\frac{1}{2}$d.

Chipping, Cross-cutting, &c.

Cross Cutting Plates.

Thickness..	$\frac{1}{8}$ in.	$\frac{1}{4}$ in.	$\frac{3}{8}$ in.	$\frac{1}{2}$ in.	$\frac{5}{8}$ in.	$\frac{3}{4}$ in.	$\frac{7}{8}$ in.	1 in.
Price per ft.	2d.	3d.	$4\frac{1}{2}$d.	6d.	$7\frac{1}{2}$d.	9d.	$10\frac{1}{2}$d.	1s.

Ripping, 3d. per foot; chipping seams, $1\frac{1}{2}$d. per foot; very thick seams, 2d. per foot.

Angle Irons, Timbers, &c.

Top, or Single Cut.		Middle Cut.	
6 in. =	4d. each.	6 in. =	5d. each.
5 in. =	$3\frac{1}{2}$d. ,,	5 in. =	$4\frac{1}{2}$d. ,,
4 in. =	3d. ,,	4 in. =	4d. ,,
3 in. =	$2\frac{1}{2}$d. ,,	3 in. =	$3\frac{1}{2}$d. ,,
2 in. =	$1\frac{1}{2}$d. ,,	2 in. =	2d. ,,

The largest side of the angle-iron is allowed.

Cross-cutting Lights.

Diameter	12 in.	9 in.	8 in.	7 in.	6 in.
Each	2s.	1s. 6d.	1s. 2d.	1s.	10d.

DRILLING AND FITTING LIGHTS.

Diameter	12 in.	9 in.	8 in.	7 in.	6 in.
Each	2s. 6d.	1s. 9d.	1s. 2d.	10d.	8d.

FIXING LIGHTS.

This includes counter-sinking, and making joints.

Diameter	12 in.	9 in.	8 in.	7 in.	6 in.
Each	2s.	1s. 6d.	1s. 2d.	1s.	10d.

The general price for drilling on the boats is 7½d. per dozen. This often both under and over.

DRILLING FOR, AND FIXING, PLUMBER WORK.

	s.	d.			s.	d.	
Side closet holes ..	2	0	each.	Kingston cock	2	6	each.
Watercourse	1	6	,,	Port lights	2	0	,,
Tank holes	1	6	,,	Scupper rings	1	6	,,
All joints making	1	3	,,	Port riddles	2	0	,,
Sluice valves	2	6	,,	Bulkhead cock	2	6	,,

Drilling 1½ in. holes = 2s. per dozen; 1⅜ in., 1¼ in., 1⅛ in. = 1s. 6d. per dozen.

TOP RIVETS.

For fixing work that cannot or must not be riveted in the usual way.

1 in., ⅞ in., ¾ in.	=	4s.	per dozen.
⅝ in.	=	3s.	,,
½ in.	=	2s.	,,
⅜ in.	=	1s. 6d.	,,

DECK BEAMS, PER FOOT.

Putting together.

12 in.	=	11d.	6 in.	=	5d.
10 in.	=	8d.	4½ in.	=	3½d.
8 in.	=	6d.			

SWEEPING ANGLE IRON FOR BEAMS.

20 feet long	4 in. × 3½ in.	=	6d.
,, ,,	3½ in. × 3 in.	=	5d.
,, ,,	3 in. × 3 in.	=	4d.
,, ,,	2½ in. × 2 in.	=	3½d.

Sweeping Beam Iron.

12 in.	=	1s.	8 in.	=	8d.
10 in.	=	10d.	6 in.	=	6d.

Straightening Angle Iron, per Foot.

6 in. × 4½ in.	=	1d.	5 in. × 3½ in.	=	½d.

Angle Iron beveled and bent, to mould, per Foot.

6 in. × 4½ in.	=	3d.	3 in. × 3 in.	=	1d.
5 in. × 3½ in.	=	2½d.	4 in. × 3 in.	=	1½d.

Shutting Deck Beams, Middle Shut.

8 in.	=	2s. 1d.	12 in.	=	2s. 11d.
10 in.	=	2s. 6d.	6 in.	=	0s. 10d.

Turning Beam Ends, Filling up, and Shutting.

10 in.	=	2s. 5d.	6 in.	=	1s. 8d.
8 in.	=	2s. 1d.			

Shutting Angle Iron.

5 in. × 3½ in.	=	1s. 6d.	2½ in. × 2½ in.	=	7d.
6 in. × 4½ in.	=	2s. 1½d.			

Angle Iron Corners.

1½ in.	=	0s. 3d.	5 in.	=	1s. 6d.
2 in.	=	0s. 5d.	5½ in.	=	1s. 10d.
3 in.	=	0s. 9d.	6 in.	=	2s. 2d.
4 in.	=	1s. 1d.	6½ in.	=	2s. 6d.
4½ in.	=	1s. 3d.	7 in.	=	2s. 10d.

Shutting Plates.

2 in.	=	0s. 2d.	11 in.	=	1s. 6d.	18 in.	=	3s. 2d.
3 in.	=	0s. 3d.	12 in.	=	1s. 9d.	19 in.	=	3s. 6d.
4 in.	=	0s. 4d.	13 in.	=	2s. 0d.	20 in.	=	3s. 10d.
5 in.	=	0s. 6d.	14 in.	=	2s. 3d.	21 in.	=	4s. 2d.
6 in.	=	0s. 8d.	15 in.	=	2s. 6d.	22 in.	=	4s. 6d.
8 in.	=	1s. 1d.	16 in.	=	2s. 9d.	23 in.	=	4s. 10d.
9 in.	=	1s. 2d.	17 in.	=	3s. 0d.	24 in.	=	5s. 2d.
10 in.	=	1s. 4d.						

Angle Iron-Joggles.

1½ in.	0s. 2d.	4½ in.	1s. 0d.
2 in.	0s. 3d.	5 in.	1s. 3d.
2½ in.	0s. 4½d.	5½ in.	1s. 6d.
3 in.	0s. 6d.	6 in.	1s. 10d.
3½ in.	0s. 8d.	6½ in.	2s. 2d.
4 in.	0s. 10d.	7 in.	2s. 6d.

	s.	d.
Shelfing, 2 ft. 1 in. × ½ in. .....per foot	0	10
„ lower deck, 1 ft. 7 in. × ½ in. „	0	7
Stringer bars on orlop deck ..... „	0	3
Shelfing, 18 inches ..... „	0	6
„ 2 ft. 6 in. × ½ in. ..... „	1	0
„ 1 ft. 6 in. × ½ in. ..... „	0	10
Bulkhead plating ..... per plate	2	6
Angle iron stiffeners..... per yard	2	6

Bending Timbers, or Frames.

7 in. × 5 in. × 50	feet long, per pair	20s.
6 in. × 4½ in. × 52	„ „	14s.
5 in. × 3½ in. × 52	„ „	14s.

Shutting Beams in Middle, to Length.

6 in.	1s. 4d.	10 in.	2s. 4d.
8 in.	1s. 10d.	12 in.	3s. 4d.

Bending and Fitting up Beam Ends.

6 in.	1s. 2d.	Middle Shuts in Beams.	6 in.	1s.	4d.
8 in.	1s. 8d.		8 in.	2s.	1d.
10 in.	2s. 4d.		10 in.	3s.	3d.

Plate joggles, double..... 1s. 0d.
„ „ single ..... 0s. 6d.

Angle Iron, Plain Shuts.

2 in. × 2 in.	0s. 4d.	5 × 3½ in.	1s. 4d.
2½ in. × 2 in.	0s. 6d.	6 × 4½ in.	2s. 0d.
3 in. × 2½ in.	0s. 8d.	7 × 5 in.	2s. 10d.
4 in. × 3½ in.	1s. 0d.		

Plate Beams, Middle Shuts.

12 in.	2s. 2d.	8 in.	1s. 5d.
10 in.	1s. 6d.	6 in.	0s. 10d.

Reverse Frames.

$4\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{5}{8}$ in., per pair ..... 10d.
4 in. × $3\frac{1}{2}$ in. × $\frac{9}{16}$ in. „ ..... 10d.

Shutting Angle Iron.

$4\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{5}{8}$ in. .. 2s. 6d. | $4\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{9}{16}$ in. .. 2s. 6d.

Bending Angle Iron for top of Floors.

$4\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{5}{8}$ in. .. 3s. | $4\frac{1}{2}$ in. × $3\frac{1}{2}$ in. × $\frac{9}{16}$ in. .. 3s.

Plating, per Ton.

	£	s.	d.		£	s.	d.
$\frac{1}{2}$ inch plates	1	16	0	$\frac{5}{16}$ inch plates	2	11	0
$\frac{7}{16}$ „ „	2	1	0	$\frac{1}{4}$ „ „	2	16	0
$\frac{3}{8}$ „ „	2	6	0	$\frac{9}{16}$ „ „	3	1	0

Engine and Paddle Beams, Plating and Smith Work, per ton, £3 5s.

	£	s.	d.
Reverse frames, per ton	1	16	0
Girders „	2	16	8
Paddle rings, each 66 feet long	1	10	0

SHIPWRIGHTS' WORK, ON THE "CLYDE,"

For a ship of 1,500 tons, equals per ton 15s. (piece work).
This does not include masts and yards.

SHIP BUILDING ON THE "THAMES" (Piece Work).

Millwall.

Riveting—			s.	d.	Riveting—			s	d.
Timbers	1	in. per yard	2	4	Keels	$1\frac{1}{4}$	in. per yard	6	0
	$\frac{7}{8}$	„	2	0		$1\frac{1}{8}$	„	4	9
	$\frac{3}{4}$	„	1	8		1	„	3	6
	$\frac{5}{8}$	„	1	3		$\frac{7}{8}$	„	2	6
	$\frac{1}{2}$	„	1	0		$\frac{3}{4}$	„	2	0
	$\frac{3}{8}$	„	0	6		$\frac{5}{8}$	„	1	6
						$\frac{1}{2}$	„	1	0
					Inside riveting—				
Seams	1	„	1	6		1	„	1	4
	$\frac{7}{8}$	„	1	4		$\frac{7}{8}$	„	1	1
	$\frac{3}{4}$	„	1	2		$\frac{3}{4}$	„	0	9
	$\frac{5}{8}$	„	0	11		$\frac{5}{8}$	„	0	8
	$\frac{1}{2}$	„	0	9		$\frac{1}{2}$	„	0	6
	$\frac{3}{8}$	„	0	4		$\frac{3}{8}$	„	0	3

Riveting—	s.	d.
Girder work—		
1 in. per yard	1	2
$\frac{7}{8}$,,	0	10
$\frac{3}{4}$,,	0	8
$\frac{5}{8}$,,	0	5
$\frac{1}{2}$,,	0	4
$\frac{3}{8}$,,	0	3
Riveting and caulking tanks—		
$\frac{3}{8}$ in. per yard	0	$3\frac{1}{2}$
Shutting angle bars—		
$1\frac{1}{2}$ in. per shut	0	3
2 ,,	0	4
$2\frac{1}{2}$,,	0	6
3 ,,	0	8
$3\frac{1}{2}$,,	0	10
4 ,,	1	0
$4\frac{1}{2}$,,	1	2
5 ,,	1	4
$5\frac{1}{2}$,,	1	8
6 ,,	2	0
$6\frac{1}{2}$,,	2	5
7 ,,	2	10
$7\frac{1}{2}$,,	3	3
8 ,,	3	8
Corners same price as shuts.		
Shutting plates—		
4 in. per shut	0	4
5 ,,	0	5
6 ,,	0	6
7 ,,	0	8
8 ,,	0	11
9 ,,	1	1
10 ,,	1	3
11 ,,	1	5
12 ,,	1	7
13 ,,	1	10
14 ,,	2	1
15 ,,	2	4
16 ,,	2	7
17 ,,	2	10
18 ,,	3	1
19 ,,	3	4
20 ,,	3	8
21 ,,	4	0
22 ,,	4	6
23 ,,	5	0
24 ,,	5	6

Shutting floor plates—	s.	d.
8 in. per shut	0	8
9 ,,	0	9
10 ,,	0	10
11 ,,	1	0
12 ,,	1	4
13 ,,	1	7
14 ,,	1	10
15 ,,	2	1
16 ,,	2	4
17 ,,	2	7
18 ,,	2	10
Shutting T iron—		
2 ,,	0	8
$2\frac{1}{2}$,,	0	10
3 ,,	1	0
$3\frac{1}{2}$,,	1	2
4 ,,	1	5
$4\frac{1}{2}$,,	1	8
5 ,,	1	11
$5\frac{1}{2}$,,	2	2
6 ,,	2	6
$6\frac{1}{2}$,,	2	10
7 ,,	3	2
$7\frac{1}{2}$,,	3	6
8 ,,	3	10

All corners same price as shuts.

Drilling and boring holes—		
1, $\frac{7}{8}$, $\frac{3}{4}$, per doz.	1	0
$\frac{5}{8}$, $\frac{1}{2}$, $\frac{3}{8}$, ,,	0	6

Plating outside of vessel, per ton—		
$\frac{7}{16}$ in. and upwards	36	0
$\frac{3}{8}$,,	42	0
$\frac{5}{16}$,,	48	0
$\frac{1}{4}$,,	54	0
$\frac{3}{16}$,,	60	0
$\frac{1}{8}$,,	66	0

The above prices including all stripping, ready for riveting.

Inside plating same price.

Bending and beveling angle iron for stringers—

		s.	d.
2	in. per foot run	0	$0\frac{1}{2}$
$2\frac{1}{2}$	,,	0	$0\frac{3}{4}$
3	,,	0	$0\frac{3}{4}$
$3\frac{1}{2}$	,,	0	$0\frac{3}{4}$
4	,,	0	1
$4\frac{1}{2}$	,,	0	1
5	,,	0	$1\frac{1}{2}$
$5\frac{1}{2}$	,,	0	$1\frac{1}{2}$
6	,,	0	2
$6\frac{1}{2}$	,,	0	$2\frac{1}{2}$
7	,,	0	3

Making angle iron, or T angle beams, and fixing—

3	in. per foot run	0	$1\frac{1}{2}$
$3\frac{1}{2}$	,,	0	$1\frac{1}{2}$
4	,,	0	2
$4\frac{1}{2}$	,,	0	2
5	,,	0	$2\frac{1}{2}$
$5\frac{1}{2}$	,,	0	$2\frac{1}{2}$
6	,,	0	3
$6\frac{1}{2}$	,,	0	3

Fixing stringers plates on deck beams, with angle iron on upper deck—

Width.		s.	d.
8 to 10	in. per foot run	0	4
12 to 16	,,	0	$4\frac{1}{2}$
16 to 20	,,	0	$5\frac{1}{2}$
20 to 24	,,	0	6
24 to 30	,,	0	$6\frac{1}{2}$

On main deck—

8 to 12	in. per foot run	0	$4\frac{1}{2}$
12 to 16	,,	0	5
16 to 20	,,	0	6
20 to 24	,,	0	$6\frac{1}{2}$
24 to 30	,,	0	7

Middle line stringers—

6 to 12	in. per foot run	0	2
12 to 18	,,	0	$2\frac{1}{2}$
18 to 30	,,	0	3

Cross-cutting plates—

		s.	d.
1	in. per foot run	1	0
$\frac{7}{8}$	,,	0	$10\frac{1}{2}$
$\frac{3}{4}$	,,	0	9
$\frac{5}{8}$	,,	0	$7\frac{1}{2}$
$\frac{1}{2}$	,,	0	6
$\frac{3}{8}$	,,	0	$4\frac{1}{2}$
$\frac{1}{4}$	,,	0	3
$\frac{1}{8}$	,,	0	2

Cross-cutting timber tops—

$1\frac{1}{2}$	in. per cut	0	1
2	,,	0	$1\frac{1}{2}$
$2\frac{1}{4}$	,,	0	$2\frac{1}{4}$
3	,,	0	$2\frac{1}{2}$
$3\frac{1}{2}$	,,	0	$2\frac{3}{4}$
4	,,	0	3
$4\frac{1}{2}$	,,	0	$3\frac{1}{2}$
5	,,	0	4
$5\frac{1}{2}$	,,	0	$4\frac{1}{2}$
6	,,	0	5
$6\frac{1}{2}$	,,	0	$5\frac{1}{2}$
7	,,	0	6
$7\frac{1}{2}$	,,	0	$6\frac{1}{2}$
8	,,	0	7

Middle cuts—

$1\frac{1}{2}$	in. per cut	0	$1\frac{1}{2}$
2	,,	0	$2\frac{1}{4}$
$2\frac{1}{2}$	,,	0	3
3	,,	0	$3\frac{1}{2}$
$3\frac{1}{2}$	,,	0	$3\frac{3}{4}$
4	,,	0	4
$4\frac{1}{2}$	,,	0	$4\frac{1}{2}$
5	,,	0	5
$5\frac{1}{2}$	,,	0	$5\frac{1}{2}$
6	,,	0	6
$6\frac{1}{2}$	,,	0	$6\frac{1}{2}$
7	,,	0	7
$7\frac{1}{2}$	,,	0	$7\frac{1}{2}$
8	,,	0	8

Making beams of bulb iron—

5	in. per foot run	0	4
6	,,	0	5
7	,,	0	$5\frac{1}{2}$

Making beams of bulb iron—

	s.	d.
8 in. per foot run	0	6
9 ,,	0	7
10 ,,	0	8
11 ,,	0	9
12 ,,	0	10

With two angle irons on the upper edge, and fixing in place.

Plate beams, with angle irons on the upper and lower edges—

5 in. per foot run	0	2½
6 ,,	0	3
7 ,,	0	4
8 ,,	0	5
9 ,,	0	6
10 ,,	0	7
11 ,,	0	8

Plate beams, with angle irons on the upper and lower edges—

	s.	d.
12 in. per foot run	0	9
13 ,,	0	10
14 ,,	0	11

Chipping seams from ½d. to 1¼d. per foot run.

Cross-cutting holes—

1 in. per foot run	1	0
⅞ ,,	0	10½
¾ ,,	0	9
⅝ ,,	0	7½
½ ,,	0	6
⅜ ,,	0	4½
¼ ,,	0	3
⅛ ,,	0	2

Fitting up beam ends, 8 in., 4s.
Middle shuts, 2s.

COST OF MARINE BOILERS, ACCORDING TO WEIGHT.

Total Weight.				Wages in Boiler Shop.			Labourers' Wages.			Total Cost.			
Tons.	cwt.	qrs.	lbs.	£	s.	d.	£	s.	d.	£	s.	d.	
84	19	3	8	1,365	11	7	33	15	0	1,399	6	7	Average Cost per ton, £17.
11	11	2	23	172	13	4	7	2	3	179	15	7	
3	7	2	0	25	15	6	2	4	3	27	19	9	
6	8	1	24	115	17	10	5	0	7	120	18	5	
61	4	0	20	997	3	8	49	7	4	1,046	11	0	
83	1	2	12	1,635	5	6	..	..	..	1,635	5	6	
12	11	3	20	150	8	10	13	14	11	164	3	9	
4	3	0	0	20	19	10	1	8	3	22	8	1	
5	3	3	24	36	19	8	4	17	5	41	17	1	
7	12	3	19	119	2	7	2	14	6	121	17	1	
6	15	0	3	37	12	6	..	6	0	37	18	6	Average Cost per ton, £10 15s.
6	15	0	3	38	8	0	..	..	..	38	8	0	
4	8	3	9	22	6	2	4	10	6	26	16	8	
31	0	0	0	223	14	10	16	5	4	240	0	2	
20	6	3	11	240	19	7	14	10	1	255	9	8	
16	4	1	9	194	4	10	10	3	3	204	8	1	
16	6	0	25	200	16	6	8	5	6	209	2	0	
70	12	1	0	805	1	1	32	10	6	837	11	7	
3	15	0	0	19	14	9	..	6	2	20	0	11	
51	18	2	20	562	11	6	8	3	6	570	15	0	
1	9	0	7	23	8	0	1	8	5	24	16	5	
53	10	0	0	543	18	4	26	6	1	570	4	5	

The preceding table gives the average cost of a number of boilers made at some of the ship-building yards on the Thames—the mean being £14 7s. 6d. per ton.

CHAIN CABLES AND ANCHORS.

Tonnage of Ship.	Diameter of Cable.	Average Weight per Fathom.	Total Weight of Anchor suitable.
tons.	inches.	lbs.	cwt.
3,000	$2\frac{1}{4}$	268	57
2,500	$2\frac{1}{8}$	244	53
2,000	$2\frac{1}{16}$	230	50
1,800	2	217	48
1,600	$1\frac{15}{16}$	201	46
1,400	$1\frac{7}{8}$	191	43
1,200	$1\frac{13}{16}$	178	40
1,000	$1\frac{3}{4}$	166	38
900	$1\frac{11}{16}$	154	35
800	$1\frac{5}{8}$	143	32
700	$1\frac{9}{16}$	132	30
600	$1\frac{1}{2}$	122	26
500	$1\frac{7}{16}$	110	23
450	$1\frac{3}{8}$	102	21
400	$1\frac{5}{16}$	93	19
350	$1\frac{1}{4}$	84	17
300	$1\frac{3}{16}$	76	15
250	$1\frac{1}{8}$	68	$12\frac{1}{2}$
200	$1\frac{1}{16}$	61	$10\frac{1}{2}$
175	1	54	9
150	$\frac{15}{16}$	48	$7\frac{1}{2}$
125	$\frac{7}{8}$	41	$6\frac{1}{2}$
100	$\frac{13}{16}$	35	5
75	$\frac{3}{4}$	30	$3\frac{1}{2}$
50	$\frac{11}{16}$	25	3
45	$\frac{5}{8}$	21	$2\frac{3}{4}$
35	$\frac{9}{16}$	17	$2\frac{1}{2}$
25	$\frac{1}{2}$	14	2

Price of cables from 2 in. diameter to $1\frac{1}{8}$ in., 15s. per cwt.

Angle Iron for Ship Building.

Per Foot Run.

Scantlings.	Weight in lbs.
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$	1·614
$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	2·310
$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{1}{4}$	2·730
$1\frac{3}{4} \times 1\frac{3}{4} \times \frac{3}{8}$	3·937
$2 \times 2 \times \frac{3}{16}$	2·402
$2 \times 2 \times \frac{1}{4}$	3·150
$2 \times 2 \times \frac{5}{16}$	3·870
$2 \times 2 \times \frac{3}{8}$	4·567
$2 \times 2 \times \frac{7}{16}$	5·237
$2 \times 2 \times \frac{1}{2}$	5·880
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{16}$	2·716
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{1}{4}$	3·570
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{16}$	4·397
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{3}{8}$	5·198
$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{7}{16}$	5·972
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8} \times \frac{1}{4}$	4·927
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{7}{16}$ bare	4·500
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	4·922
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$ bare	5·827
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{7}{16}$ bare	6·700
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2}$ bare	7·560
$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2} \times \frac{5}{16}$	6·300
$2\frac{3}{4} \times 2\frac{3}{4} \times \frac{1}{4}$	4·410
$3 \times 2 \times \frac{1}{4}$	3·990
$3 \times 1\frac{1}{4} \times \frac{3}{8} \times \frac{3}{8}$	4·515
$3 \times 3 \times \frac{1}{4}$	4·830
$3 \times 2\frac{1}{2} \times \frac{3}{8}$	5·565
$3 \times 3 \times \frac{5}{16}$	5·972
$3 \times 3 \times \frac{3}{8} \times \frac{1}{4}$	5·985
$3 \times 2\frac{1}{2} \times \frac{3}{8}$	6·457
$3 \times 3 \times \frac{3}{8}$	7·087
$3 \times 3 \times \frac{1}{2}$ bare	8·190
$3 \times 3 \times \frac{1}{2}$	9·240
$3 \times 3 \times \frac{5}{8}$	11·287
$3 \times 2\frac{1}{4} \times \frac{3}{8}$	11·34
$3\frac{1}{4} \times 2\frac{3}{4} \times \frac{1}{2} \times \frac{3}{16}$ ...	7·822
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{4}$	
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8} \times \frac{5}{16}$	7·691
$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	7·087
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	8·347
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{16}$ full	8·00
$3\frac{1}{2} \times 3 \times \frac{1}{2} \times \frac{3}{8}$	9·03
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	10·92
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{5}{16}$	12·167
$4 \times 3\frac{1}{2} \times \frac{3}{8}$	13·387
$4 \times 2 \times \frac{1}{4}$	14·83
$4 \times 2\frac{1}{2} \times \frac{5}{16}$	8·912
$4 \times 3 \times \frac{3}{8}$	8·347
$4 \times 3 \times \frac{5}{8}$	13·4
$4 \times 4 \times \frac{1}{4}$	6·51
$4 \times 4 \times \frac{3}{8}$	9·607
$4 \times 4 \times \frac{3}{8}$ full.....	10·3
$4 \times 3 \times \frac{1}{2}$	10·92
$4 \times 4 \times \frac{1}{2}$	12·60
$4 \times 4 \times \frac{7}{12}$	13·33
$4 \times 4 \times \frac{9}{16}$	14·53
$4 \times 4 \times \frac{5}{8}$	15·487
$4 \times 4 \times \frac{3}{4}$	18·27
$4\frac{1}{2} \times 3 \times \frac{3}{8}$	8·977
$4\frac{1}{2} \times 3\frac{1}{8} \times \frac{3}{8} \times \frac{5}{16}$	9·345
$5 \times 5 \times \frac{7}{16}$	14·057
$5 \times 5 \times \frac{5}{8}$	19·687
$5\frac{1}{2} \times 5\frac{1}{2} \times \frac{1}{2}$	13·44
$6 \times 2\frac{1}{4} \times \frac{3}{8}$	9·922
$6 \times 6 \times \frac{5}{8}$	23·887

Machines used in Ship Building.

	£	s.	d.
12 feet rolls	200	0	0
Steam punching and shearing (3 punches) ..	600	0	0
Plate planing machine	100	0	0
Punching machine and table (2 punches)	300	0	0

SPECIFICATION OF A SCREW STEAM VESSEL OF $1767\frac{65}{94}$ TONS.

Service.—The vessel is to be employed in the conveyance of the mails and passengers between New Zealand and ———, a distance of about 7,000 knots, without a calling station. She is to be provided with water ballast-tanks, containing about 100 tons, to compensate in a measure for the lightening of the ship, as the fuel is consumed.

Performance.—The vessel is to carry 1,200 tons of coal, in holds, bunkers, and water ballast-tanks, in addition to other necessary stores, and when so loaded she is to run an average of 13 knots per hour under steam only, with a consumption of coals not exceeding $27\frac{1}{4}$ tons per day of 24 hours. The purchasers are to decide on the duration of the trial, which is to be undertaken at the risk and cost of the builders.

Guarantee.—The builders are to guarantee the purchasers free from cost of rectifying any accident, arising from defective proportions, material, or workmanship, which may occur to either ship or machinery for twelve months after the final completion of the work.

Time of Completion.—The vessel to be completed and ready for service within eight calendar months after date of order.

Accommodation.—The vessel is to have a saloon and other accommodation for as many passengers as can be put on main deck. The fittings of cabins to be equal to those of vessels of similar services, belonging to the Peninsular and Oriental Steam Navigation Company. She is to have mail, post office, sorting, specie, and baggage rooms, also all necessary store-rooms for the accommodation of officers and crew.

Class.—She is to be built under Lloyd's special survey, and to be classed A A as a spar deck ship. Should any scantlings or other details in this specification be shown, to the satisfaction of the company's surveyor, to differ from the requirements for the above class, such parts are to be modified accordingly.

Certificate.—The vessel is to be provided with a Board of Trade certificate.

Drawings.—Drawings showing the detail arrangements of cabins, &c., are to be submitted to the builders, and must be approved of in writing by the purchasers.

Specification.—The specification is not supposed to indicate every detail which will require the attention of the builders. It is given as a fair description of the class of vessel required. The vessel is to be completed and equipped, in all points, equal to any ship of her class, notwithstanding any omission in the specification of items necessary for that purpose, excepting only chronometers, plate, linen, cutlery, stone-ware, glass, and bedding. No payment will be made beyond the contract price of the ship on account of *extra work or materials*, unless the same shall have been authorised in writing as extras by the purchasers.

Surveyors.—The whole of the work to be done to the satisfaction of the company's surveyors and inspector, who are to have free access to inspect the progress of the work during all ordinary working hours while the ship is building; and they are to have power to reject any material, or workmanship, which in their judgment is not in accordance with agreement.

Payments.—Payments will be made on the certificates of the surveyors that the work has proceeded to their satisfaction to the stages at which payments are agreed to be made.

Materials.—All materials used in the construction of the ship are to be the best of the respective descriptions. The iron is to be of such quality that the tensile strain requisite to break it shall not be less than 20 tons per sectional square inch on the dimensions of the bar before it is tested. The builders are to test any portion of the iron, and in every way satisfy the surveyors that it is of a suitable quality. Each plate and bar is to be branded with the maker's name.

General Specification of Workmanship.

The butts of all plating and stringers, as well as those of centre plates, and side bars of intercostal keelson and keel, are to be planed and drawn hard together.

All butt-strips are to be equal in section to the plates or angle-irons they are intended to connect, and are to be so cut that the grain of the iron runs in the same direction as that of the parts to which they are attached.

Butt-strips on beam-stringers and ties to be on the underside.

All lugs or short second reverse bars on frames, for the attachment

of stringers, are to be of the same scantling as reverse bars, and fixed with at least four rivets.

The liners behind frames at alternate strakes of outside plating, and wherever required, are to be in one piece, accurately filling the space in length, breadth, and thickness.

All counter-sinking is to be done through the entire thickness of the plate.

The rivet holes to be fairly opposite each other. Should any unfair holes occur they are to be rhymered out. The holes are to be punched from opposite sides of parts to be connected together; so that the small end of the tapered holes, formed by the act of punching, may lie against each other.

The rivets are completely to fill the holes, are all to be laid up close round their heads, and those in countersinks are to be cut off outside, fair with the surface of the plates, excepting those through starboard strakes and keel, where they should be slightly rounded. Wherever double or treble riveting is required the rivets are to be in straight rows, square with the edge of the plate (chain riveting), and are not in any case to be "zig-zag."

All surfaces riveted together are to bear fairly against each other, through their length and width, so that a knife, the thickness of which does not exceed No. 26 Birmingham wire gauge, cannot be introduced between them at any part.

All stringers are to be continued fore and aft, bulkheads and other obstructions to be notched and made good up to them. Wherever a stringer has to be cut, as in the engine-room, or elsewhere, the loss of strength is to be compensated for by other arrangements, to be approved of by the company's surveyors.

It will be preferred that the floor plates, and reverse bars, as well as the various angle-iron lugs, be riveted to each frame before it is set up in position. It will also be preferred that the landing holes in the frames to receive the seams of outside plating be marked from the plates, and drilled.

Dimensions.

	Feet	in.
Length between perpendiculars	285	0
Beam	35	6
Depth from top of floors to top of spar deck	26	8

Tonnage O.B.M.	$1767\frac{65}{94}$ tons
Engines, nominal	350 H.P.

Keel.—To be formed of a centre plate 35″ × $\frac{11}{16}$″, with two side plates 9″ × $1\frac{3}{16}$″ at the bottom, with a flat plate on top of floors 36″ × $\frac{14}{16}$″, and two angle irons 5″ × 6″ × $\frac{9}{16}$″.

Stem.—Of best scrap iron, average size 9″ × 3″, properly scarped and attached to keel.

Frames.—Of angle iron 5″ × 3″ × $\frac{9}{16}$″, spaced 21″ apart from centre to centre throughout.

Reverse Bars.—Of angle iron 3″ × $3\frac{1}{2}$″ × $\frac{1}{2}$″, extending to main deck and spar deck alternately.

Floors.—Of plate iron 26″ × $\frac{1}{2}$″ at centre, and $\frac{1}{2}$″ at ends, tapering in depth to size of frame at bilge.

Intercostal Keelsons.—To have an intercostal keelson on each side of main keelsons, of plate $\frac{11}{16}$″ thick, fitted between the floors, as far as engine and boiler-room extends, with double angle iron 5″ × 6″ × $\frac{9}{16}$″ on each side of the plate, and continued as much farther forward and aft as may be thought necessary.

Bilge Keelson.—To be framed of two bars of angle iron 6″ × 5″ × $\frac{9}{16}$″, carried as far fore and aft as it can be got. To be riveted to double reverse angle irons, and to have an $8\frac{1}{2}$″ × $\frac{9}{16}$″ bulb-plate betwixt as far as engine and boiler-room extends.

Spar Deck Beams.—Of bulb iron $8\frac{1}{2}$″ × $\frac{1}{2}$″, with knees properly on, and double angle iron on upper edge $2\frac{1}{2}$″ × $2\frac{1}{2}$″ × $\frac{5}{16}$″.

Main and Lower Deck Beams.—Of bulb iron $8\frac{1}{2}$″ × $\frac{1}{2}$″, with knees properly welded on, and double angle iron on upper edge $3\frac{1}{2}$″ × $3\frac{1}{2}$″ × $\frac{3}{8}$″.

Beam Stancheons.—To be provided where necessary.

Spar Deck Stringers.—Of plate iron 36″ × $\frac{10}{16}$″ amidships, tapering to 27″ × $\frac{10}{16}$″ at ends, with angle iron 5″ × $4\frac{1}{2}$″ × $\frac{9}{16}$″ all round the ship.

Main Deck Stringers.—Of plate iron 42″ × $\frac{3}{4}$″ amidships, tapering to $31\frac{1}{2}$″ × $\frac{11}{16}$″ at ends, fitted to skin with a 5″ × $4\frac{1}{2}$″ × $\frac{9}{16}$″ angle iron riveted to skin and stringer, and a continuous bar 5″ × $4\frac{1}{2}$″ × $\frac{9}{16}$″ carried all round the ship inside of the frames.

Lower Deck Stringer.—Of plate iron $31\frac{1}{2}$″ × $\frac{10}{16}$″ all round the ship, with an angle iron 5″ × $4\frac{1}{2}$″ × $\frac{9}{16}$.″

Bilge Stringer.—Of two bars of angle iron 5″ × $4\frac{1}{2}$″ × $\frac{9}{16}$″, riveted back to back, and to double reverse bars placed between the bilge keelson and lower deck stringers.

Deck Ties.—On spar deck to be 14″ × $\frac{10}{16}$″; on main and lower deck, 14″ × $\frac{10}{18}$″, placed on each side of hatchways.

Bulkheads.—To have four water-tight bulkheads carried up to

main deck of $\frac{7}{16}$″ plate iron, stiffened with $3\frac{1}{2}$″ × 3″ × $\frac{1}{2}$″ angle iron, and fitted with two sluice valves to each, worked from main deck.

Outside Plating.—Garboard strakes . . . . $\frac{13}{16}$″.
Bottom . . . . . $\frac{12}{16}$″.
Sides . . . . . $\frac{11}{16}$″ and $\frac{10}{16}$″.
Main shear double $\frac{3}{4}$-length . $\frac{12}{16}$″.

Rudder.—Stock $7\frac{1}{2}$″ diameter, with 4″ pintles $3\frac{1}{2}$″ diameter, the frame all welded in one piece, and plated with $\frac{5}{16}$″ plates; to have a stuffing-box on deck, and fitted with a screw steering apparatus and two teak steering wheels.

Riveting.—The whole of the riveting to be as per Lloyd's Rules, of the best material and workmanship.

Water Tanks.—To contain 3,000 gallons, with plumbing work complete.

Coal Bunkers.—To suit arrangement with engines.

Wood-work.

Water Ways.—Of main and spar deck of teak, as per Lloyd's, well secured by bolts and nuts.

Deck.—Of sound yellow pine, free from objectionable knots, shakes, or other defects. Spar deck, 5″ × 3″; main deck, 6″ × 4″, securely bolted with galvanized bolts and nuts, and dowelled. Teak plank to be laid for capstans, stoppers, riding bitts, where eye-bolts have to be fixed, and in range of chain cable. The space below beams under capstan to be filled in solid, and lined with 2″ elm plank.

Hatch Combings.—Of oak or teak 4″ thick, protected with iron, galvanized.

Bulwark Stanchions.—Of oak or teak 5″ × $4\frac{1}{2}$″, with cleading of $1\frac{3}{4}$-inch thick, lined and panelled inside, except foreward and aft, where the iron-work will be carried up.

Main Rail.—Of teak 11″ × 3″, protected with yellow metal where any chafing may be expected.

Ceiling in Bunker and Hold.—To be of American elm, $2\frac{1}{2}$″ thick to under side of bilge stringer, there to be fitted between frames and caulked, above this to be sparred 6″ berth, and space with 2″ stuff.

Hawse Pipes.—Four in number, two on each bow, of cast iron, properly fitted and secured; other pipes as required.

Cat Heads.—Of wood or iron, as may be arranged, with stoppers complete.

Top-sail Sheet Bitts.—Round masts to be of teak, capped with brass.

Boats.—To have a full set of boats as required by the Board of Trade, complete with blocks, falls, spars, &c., and two sets of lowering apparatus.

Bollards.—Of sufficient dimensions and in number as may be required, with mooring pipes and fair leaders as may be arranged.

Scuppers.—Of lead of the best construction.

Anchor Davits.—Fitted with blocks, falls, &c., complete.

Chains and Anchors.—As per Lloyd's Rules, properly tested and the certificate given to the purchasers.

Chain Lockers.—To be fitted of elm, $2\frac{1}{2}$ inches thick, in a convenient position, with a provision for getting inside to stow cable.

Anchor Capstans.—Of approved construction, with movable stops, wrought iron bitts, &c., and worked by steam power.

Warping Capstans.—To be placed in position to be arranged.

Cabins.—Arranged according to a plan to be approved of; fitted in a comfortable, substantial, and elegant manner, with cabinet work and upholstery work complete, with tables and oiled covers to each, seats, sideboards, mirrors, and clocks, stoves, water-closets, baths, and basins, with ewers and tank complete.

This work to be done in a manner similar in vessels recently built by the P. and O. Company.

Officers and Seamen.—Accommodation as arranged for on the plan to be approved of.

Ventilation.—The cabins and engine-room with suitable apparatus.

Galley.—To be fitted with approved cooking and distilling apparatus, sufficient for crew and passengers. Floor fitted with tiles.

Mail Room.—Specie-room, post office, sorting-room, store-rooms, &c., to be fitted up in the best manner, and as arranged on drawing to be approved of.

Hen-coops, Sheep-pens, &c.—To be of teak, made and fitted where may be arranged.

Carving.—To be neatly executed in accordance with the name of the ship.

Rigging.—The vessel to be barque-rigged, according to plan to be approved of, with a full set of masts and spars. The lower masts to be iron, fitted with lightning conductors. Standing rigging of galvanized wire rope; remainder, of hemp and manilla, fitted with a complete set of blocks and dead-eyes, and all iron-work connected therewith; dead-eyes to be of lignum-vitæ; halyard

brace-blocks to have patent roller bushes; chain plates to be outside, on channels.

Sails.—To have two complete suits of sails of best long flax canvas, the number to be hereafter decided by company's superintendent; one suit of sail covers to be provided; two of the boats to be fitted with masts and sails.

Awning.—To be fitted to cover the entire spar deck, with stancheons of galvanized iron, ridge ropes and all complete.

Winches.—To have two steam winches, with derricks, gins, and chains complete.

Side Ports.—To have brass side ports, two to each cabin and state room, all 10″ diameter in the light. Iron port-riddles to be provided outside, riveted to plating.

Water Ballast.—Tanks, or water-holds, to be provided, capable of containing 100 tons of water, with all requisite fittings for filling the same, and emptying them from the engine-room.

Screw Tunnel.—To be provided as required for the engines, and to be fitted with a water-tight door at engine bulkhead.

Plumbing and Glazing.—To be done in the best and most substantial manner; all glazing to be in best plate-glass.

Hawsers as required by Board of Trade.

Skylights.—Companions and other deck fittings to be of teak.

Galvanizing.—All stancheons, eye-bolts, &c., above deck, to be galvanized.

Boats' Davits.—Of iron, of the requisite number and size, and securely fixed.

Pumps.—To have a 6″ pump on each deck, with all proper connections, and to be fitted to pump from holds and sea, and act as a fire-engine, the requisite length of leather hose for direction-pipes being provided; also pumps on each deck from fresh-water tank.

Compasses.—To have four compasses with 12 cards, with binnacle lamps, and complete. One compass fitted as a standard compass (Cameron's Azimuth), to be at such elevation above deck and in such a position as may be thought advisable.

The steering compass to be one of West's Liquid, London. The other two compasses to be by Blackney, on his improved anti-vibration principle. Adjustments of compasses to be made by a competent person, appointed by or approved by the purchasers.

Bells.—To have two bells, one in a brass and the other in a cast-iron belfry, with ship's name engraved thereon.

Flags.—One Barque, one Union Jack, one Blue Peter, one Company's flag, and a full code of signals, with books, all fitted in lockers.

Accommodation Ladders.—One on each side, with platform davits and fittings complete; these and all other ladders to be of teak.

Guns.—To have two 9-pounder guns, with two ports forward, and two aft.

Cement.—Vessel to be coated with approved composition inside, and an approved paint outside.

Painting.—All the iron-work to receive two coats of red-lead, or other approved paint. The outside to have other two coats, as the superintendents may approve. All wood-work, where not grained and varnished, to receive four coats of paint, or if grained, to have two coats of paint besides varnish.

Lamps.—The set of Admiralty signal lamps, three globe hold lanterns, cook's lanterns, and two forecastle lamps. Also proper lamps for saloon and cabins throughout ship.

Life Buoys.—Four buoys with ship's name on each, and four cork fenders.

Tarpaulings.—Two tarpaulings for each cargo hatch, covers for wheel binnacles, skylights and boats.

Cooper's Stores.—1 dozen deck buckets.
1 ,, fire ,,
1 ,, mess kids
4 harness casks
2 steep tubs with galvanized iron hoops.

SUNDRIES.

Brass speaking trumpet.
1 fog horn.
1 14-second glass.
1 28 ,,
1 deep-sea lead and line.
2 hand leads and lines.
1 log reel.
2 ,, lines.
1 patent log and line.
1 grindstone and trough.
1 dozen paint scrubs.
1 ,, paint brushes.
1 ,, brooms, assorted.
2 ,, hooks and thimbles.
1 ,, marline spikes.
1 ,, deck scrapers.
1 dozen coir door mats.
½ ,, paint pots.
½ ,, mops.
½ ,, ballast shovels.
½ ,, cold chisels.
3 snatch blocks.
3 dozen spare blocks, assorted.
1 spare cat block.
1 dozen serving boards and mallets.
2 dozen sail needles.
½ ,, sail hooks.
½ ,, handspikes.
1 ,, hanks.
1 pitch pot and ladle.
4 oil feeders.

2 oil funnels.
1 cross-cut saw.
1 axe.
6 chisels.
1 hand-saw.
2 tillers.
1 safety hold lantern.
1 spare shackle, fall and anchor.
1 dozen chain hooks.
2 hooks for fishing anchor.
2 chain stoppers.
2 shank painters.
6 assorted crate and other hooks.
6 crowbars.
2 dozen hooks and thimbles, assorted.
2 dozen firelocks.
6 „ pairs handcuffs.
2 „ carpet stools.

Cordage.—One ton of rope—marline.

Stores.—Spun yarn, houseline, or twine, all inclusive, will be allowed as the extra stores on board of the ship.

Scantlings.—According to Lloyd's.

This may be considered a fair example of a specification for a ship of the class. Of course, from time to time alterations may occur; the author merely gives it as a guide to go by.

KEEL, STEM AND STERN POSTS FOR ALL GRADES.

Gross Tonnage.			Inches.
100	and under	200	6 × 1½
200	„	300	6¼ × 2
300	„	400	6½ × 2¼
400	„	500	6¾ × 2½
500	„	600	7 × 2½
600	„	700	7 × 2¾
700	„	800	7¼ × 2¾
800	„	900	7½ × 3
900	„	1,000	8 × 3
1,000	„	1,200	8½ × 3
1,200	„	1,500	9 × 3
1,500	„	2,000	10 × 3
2,000	„	2,500	12 × 3
2,500	„	3,000	12 × 3¼
3,000	„	3,500	12 × 3½

FRAMES.

Distance of frames from moulding edge to moulding edge, all fore and aft for all grades.

If single frames be adopted, the space from centre to centre is not to exceed 21 inches, all fore and aft;

but provided an additional frame, for half the vessel's length amidships, be fitted at opposite side of each floor across the keel, and extended to upper part of bilges, and riveted through floor plates and main frames, also through the outside plating, as required for main frames, the space may be increased to 23 inches, in ships under 1,000 tons, and to 24 inches in ships of 1,000 tons and upwards.

DIMENSIONS FOR ANGLE IRON FOR ALL GRADES.

Gross Tonnage.	Inches.
100 and under 200	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{6}{16}$
200 „ 300	$3 \times 2\frac{1}{2} \times \frac{6}{16}$
300 „ 400	$3\frac{1}{4} \times 2\frac{3}{4} \times \frac{6}{16}$
400 „ 500	$3\frac{1}{2} \times 2\frac{3}{4} \times \frac{7}{16}$
500 „ 600	$3\frac{3}{4} \times 2\frac{3}{4} \times \frac{7}{16}$
600 „ 700	$4 \times 3 \times \frac{7}{16}$
700 „ 800	$4\frac{1}{4} \times 3 \times \frac{8}{16}$
800 „ 900	$4\frac{1}{2} \times 3 \times \frac{8}{16}$
900 „ 1,000	$4\frac{3}{4} \times 3 \times \frac{8}{16}$
1,000 „ 1,200	$5 \times 3 \times \frac{9}{16}$
1,200 „ 1,500	$5 \times 3\frac{1}{2} \times \frac{9}{16}$
1,500 „ 2,000	$5\frac{1}{2} \times 3\frac{1}{2} \times \frac{10}{16}$
2,000 „ 2,500	$6 \times 4 \times \frac{10}{16}$
2,500 „ 3,000	$6\frac{1}{4} \times 4 \times \frac{11}{16}$
3,000 „ 3,500	$6\frac{1}{2} \times 4 \times \frac{11}{16}$

REVERSE ANGLE IRONS, ON FRAMES, BULKHEADS, AND BOX KEELSONS, FOR ALL GRADES.

Gross Tonnage.	Inches.
100 and under 200	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{16}$
200 „ 300	$2\frac{1}{4} \times 2\frac{1}{4} \times \frac{5}{16}$
300 „ 400	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$
400 „ 500	$2\frac{3}{4} \times 2\frac{1}{2} \times \frac{6}{16}$
500 „ 600	$3 \times 2\frac{1}{2} \times \frac{6}{16}$
600 „ 700	$3 \times 2\frac{3}{4} \times \frac{6}{16}$
700 „ 800	$3 \times 2\frac{3}{4} \times \frac{7}{16}$
800 „ 900	$3 \times 3 \times \frac{7}{16}$
900 „ 1,000	$3\frac{1}{4} \times 3 \times \frac{7}{16}$

REVERSE ANGLE IRONS—(*continued*).

Gross Tonnage.			Inches.
1,000 and under	1,200	.....	$3\frac{1}{2} \times 3 \times \frac{8}{16}$
1,200	,, 1,500	.....	$3\frac{1}{2} \times 3 \times \frac{9}{16}$
1,500	,, 2,000	.....	$4 \times 3\frac{1}{2} \times \frac{9}{16}$
2,000	,, 2,500	.....	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{9}{16}$
2,500	,, 3,000	.....	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{10}{16}$
3,000	,, 3,500	.....	$4\frac{1}{2} \times 3\frac{1}{2} \times \frac{10}{16}$

THICKNESS OF OUTSIDE PLATES.

GARBOARD STRAKES, AND SINGLE PLATE; MIDDLE LINE KEELSONS STANDING UP ON FLOORS.

Gross Tonnage.			A Inches.	B Inches.
100 and under	200	.....	$\frac{7}{16}$	$\frac{7}{16}$
200	,, 300	.....	$\frac{9}{16}$	$\frac{8}{16}$
300	,, 400	.....	$\frac{10}{16}$	$\frac{9}{16}$
400	,, 500	.....	$\frac{10}{16}$	$\frac{9}{16}$
500	,, 600	.....	$\frac{11}{16}$	$\frac{10}{16}$
600	,, 700	.....	$\frac{11}{16}$	$\frac{10}{16}$
700	,, 800	.....	$\frac{12}{16}$	$\frac{11}{16}$
800	,, 900	.....	$\frac{12}{16}$	$\frac{11}{16}$
900	,, 1,000	.....	$\frac{13}{16}$	$\frac{12}{16}$
1,000	,, 1,200	.....	$\frac{13}{16}$	$\frac{12}{16}$
1,200	,, 1,500	.....	$\frac{14}{16}$	$\frac{13}{16}$
1,500	,, 2,000	.....	$\frac{14}{16}$	$\frac{13}{16}$
2,000	,, 2,500	.....	$\frac{15}{16}$	$\frac{14}{16}$
2,500	,, 3,000	.....	$\frac{15}{16}$	$\frac{14}{16}$
3,000	,, 3,500	.....	$\frac{16}{16}$	$\frac{15}{16}$

FROM GARBOARD TO UPPER PART OF BILGE AND THE SHEER-STRAKES.

Gross Tonnage.			A Inches.	B Inches.
100 and under	200	.....	$\frac{7}{16}$	$\frac{6}{16}$
200	,, 300	.....	$\frac{8}{16}$	$\frac{7}{16}$
300	,, 400	.....	$\frac{9}{16}$	$\frac{8}{16}$
400	,, 500	.....	$\frac{9}{16}$	$\frac{8}{16}$
500	,, 600	.....	$\frac{10}{16}$	$\frac{9}{16}$
600	,, 700	.....	$\frac{10}{16}$	$\frac{9}{16}$
700	,, 800	.....	$\frac{11}{16}$	$\frac{10}{16}$
800	,, 900	.....	$\frac{11}{16}$	$\frac{10}{16}$
900	,, 1,000	.....	$\frac{12}{16}$	$\frac{11}{16}$
1,000	,, 1,200	.....	$\frac{12}{16}$	$\frac{11}{16}$
1,200	,, 1,500	.....	$\frac{13}{16}$	$\frac{12}{16}$
1,500	,, 2,000	.....	$\frac{13}{16}$	$\frac{12}{16}$
2,000	,, 2,500	.....	$\frac{14}{16}$	$\frac{13}{16}$
2,500	,, 3,000	.....	$\frac{14}{16}$	$\frac{13}{16}$
3,000	,, 3,500	.....	$\frac{15}{16}$	$\frac{14}{16}$

FROM UPPER PART OF BILGE TO A PERPENDICULAR HEIGHT; FROM UNDER SIDE OF KEEL OF THREE-FIFTHS THE INTERNAL DEPTH OF HOLD, MEASURED FROM THE UPPER SIDE OF UPPER DECK IN ALL SHIPS, WHETHER SPAR-DECKED OR OTHERWISE.

Gross Tonnage.			A Inches.	B Inches.
100 and under		200	6/16	5/16
200	„	300	7/16	6/16
300	„	400	8/16	7/16
400	„	500	8/16	7/16
500	„	600	9/16	8/16
600	„	700	9/16	8/16
700	„	800	10/16	9/16
800	„	900	10/16	9/16
900	„	1,000	11/16	10/16
1,000	„	1,200	11/16	10/16
1,200	„	1,500	12/16	11/16
1,500	„	2,000	12/16	11/16
2,000	„	2,500	13/16	12/16
2,500	„	3,000	13/16	12/16
3,000	„	3,500	14/16	13/16

FROM THREE-FIFTHS THE DEPTH OF HOLD (MEASURED FROM THE UPPER SIDE OF UPPER DECK IN ALL SHIPS, WHETHER SPAR-DECKED OR OTHERWISE), TO LOWER EDGE OF SHEERSTRAKE.

Gross Tonnage.			A Inches.	B Inches.
100 and under		200	6/16	5/16
200	„	300	6/16	6/16
300	„	400	7/16	6/16
400	„	500	7/16	6/16
500	„	600	8/16	7/16
600	„	700	8/16	7/16
700	„	800	9/16	8/16
800	„	900	9/16	8/16
900	„	1,000	10/16	9/16
1,000	„	1,200	10/16	9/16
1,200	„	1,500	11/16	10/16
1,500	„	2,000	11/16	10/16
2,000	„	2,500	12/16	11/16
2,500	„	3,000	12/16	11/16
3,000	„	3,500	12/16	11/16

THICKNESS OF STRINGER PLATES UPON BEAMS, FLOOR-PLATE HOOKS, CRUTCHES, AND BOX OR INTERCOSTAL KEELSONS, FOR ALL GRADES.

Gross Tonnage.			Inches.
100 and under 200			$\frac{6}{16}$
200	„	300	$\frac{6}{16}$
300	„	400	$\frac{7}{16}$
400	„	500	$\frac{7}{16}$
500	„	600	$\frac{8}{16}$
600	„	700	$\frac{8}{16}$
700	„	800	$\frac{9}{16}$
800	„	900	$\frac{9}{16}$
900	„	1,000	$\frac{10}{16}$
1,000	„	1,200	$\frac{10}{16}$
1,200	„	1,500	$\frac{11}{16}$
1,500	„	2,000	$\frac{11}{16}$
2,000	„	2,500	$\frac{12}{16}$
2,500	„	3,000	$\frac{12}{16}$
3,000	„	3,500	$\frac{12}{16}$

THICKNESS OF PLATES FOR BULKHEADS, FOR ALL GRADES.

Gross Tonnage.			Inches.
100 and under 200			$\frac{4}{16}$
200	„	300	$\frac{4}{16}$
300	„	400	$\frac{5}{16}$
400	„	500	$\frac{6}{16}$
500	„	600	$\frac{6}{16}$
600	„	700	$\frac{6}{16}$
700	„	800	$\frac{6}{16}$
800	„	900	$\frac{6}{16}$
900	„	1,000	$\frac{7}{16}$
1,000	„	1,200	$\frac{7}{16}$
1,200	„	1,500	$\frac{7}{16}$
1,500	„	2,000	$\frac{8}{16}$
2,000	„	2,500	$\frac{8}{16}$
2,500	„	3,000	$\frac{8}{16}$
3,000	„	3,500	$\frac{9}{16}$

DIMENSIONS OF ANGLE IRON ON BEAM, STRINGERS OR KEELSONS, FOR ALL GRADES.

Gross Tonnage.	Inches.
100 and under 200	3 × 3 × $\frac{6}{16}$
200 „ 300	3 × 3 × $\frac{6}{16}$
300 „ 400	$3\frac{1}{2}$ × 3 × $\frac{6}{16}$
400 „ 500	4 × 3 × $\frac{6}{16}$
500 „ 600	$4\frac{1}{4}$ × $3\frac{1}{4}$ × $\frac{7}{16}$
600 „ 700	$4\frac{1}{2}$ × $3\frac{1}{2}$ × $\frac{7}{16}$
700 „ 800	$4\frac{3}{4}$ × $3\frac{1}{4}$ × $\frac{8}{16}$
800 „ 900	5 × 4 × $\frac{8}{16}$
900 „ 1,000	5 × $4\frac{1}{4}$ × $\frac{9}{16}$
1,000 „ 1,200	5 × $4\frac{1}{2}$ × $\frac{9}{16}$
1,200 „ 1,500	$5\frac{1}{2}$ × $4\frac{1}{2}$ × $\frac{9}{16}$
1,500 „ 2,000	6 × 5 × $\frac{9}{16}$
2,000 „ 2,500	$6\frac{1}{2}$ × $5\frac{1}{2}$ × $\frac{10}{16}$
2,500 „ 3,000	$6\frac{1}{2}$ × $5\frac{1}{2}$ × $\frac{10}{16}$
3,000 „ 3,500	$6\frac{1}{2}$ × $5\frac{1}{2}$ × $\frac{10}{16}$

RUDDER, FOR ALL GRADES.

Gross Tonnage.	Diameter at Head.	Diameter at Heel.	Thickness of Wood Flat of Upper Deck.
	in.	in.	in.
100 and under 200	3	2	$2\frac{1}{2}$
200 „ 300	$3\frac{1}{2}$	2	$2\frac{1}{2}$
300 „ 400	$3\frac{3}{4}$	$2\frac{1}{4}$	3
400 „ 500	$4\frac{1}{2}$	$2\frac{1}{2}$	3
500 „ 600	$4\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{2}$
600 „ 700	$4\frac{3}{4}$	$2\frac{3}{4}$	$3\frac{1}{2}$
700 „ 800	5	3	$3\frac{1}{2}$
800 „ 900	$5\frac{1}{4}$	3	$3\frac{1}{2}$
900 „ 1,000	$5\frac{1}{2}$	3	$3\frac{1}{2}$
1,000 „ 1,200	$5\frac{3}{4}$	3	4
1,200 „ 1,500	6	$3\frac{1}{4}$	4
1,500 „ 2,000	$6\frac{1}{2}$	$3\frac{1}{2}$	4
2,000 „ 2,500	$7\frac{1}{4}$	$3\frac{3}{4}$	4
2,500 „ 3,000	$7\frac{3}{4}$	4	4
3,000 „ 3,500	8	$4\frac{1}{2}$	4

The scantlings given are intended for ships, the length of which, measured from the fore part of the stem to the after part of the stern-post, on the range of the upper deck, does not exceed seven times their

breadth, or ten times their depth of hold, taken from the upper part of the floors to the top of the upper deck beams.

DIAMETER OF RIVETS REQUIRED FOR THICKNESS OF PLATES.

Diameter of Rivets	in. $\frac{5}{8}$			in. $\frac{3}{4}$			in. $\frac{7}{8}$			in. 1		
Thickness of Plates	$\frac{5}{16}$	$\frac{6}{16}$	$\frac{7}{16}$	$\frac{8}{16}$	$\frac{9}{16}$	$\frac{10}{16}$	$\frac{11}{16}$	$\frac{12}{16}$	$\frac{13}{16}$	$\frac{14}{16}$	$\frac{15}{16}$	$\frac{16}{16}$

Rivets to be $\frac{1}{4}$ of an inch larger in diameter in the stem, sternpost, and keel.

IRON SHIPS.

BUILDERS' MEASURE *v.* REGISTER TONNAGE.

By Mr. Robert Duncan.

The mode of calculating regular tonnage by ratios is exceedingly simple. The useful limit of ratios for merchant vessels is from ·55 to ·75 of the parallelopiped dimensions; every decimal to three or four places, and any degree of fineness or fulness, as required either for high speed or low speed; multiply the length between perpendiculars (including the rake of stern-post to main deck), the breadth extreme, and the depth of hold together, and the sum by the ratio of fineness desired, divided by 100; the result will be the tonnage under deck (main or spar deck, as may be), which may be easily produced on plan by decimal sections designed to the ratio of form required.

Thus, for the dimensions already quoted, $205 \times 34{\cdot}5 = 1{,}166$, builders' measurement, on any depth; the register calculated for 20 feet depth by ratio ·6 is as follows:—

$205 \times 34{\cdot}5 \times 20 = 848{\cdot}\frac{70}{100}$ tons under main deck.

34·5

7072·5

20

141450

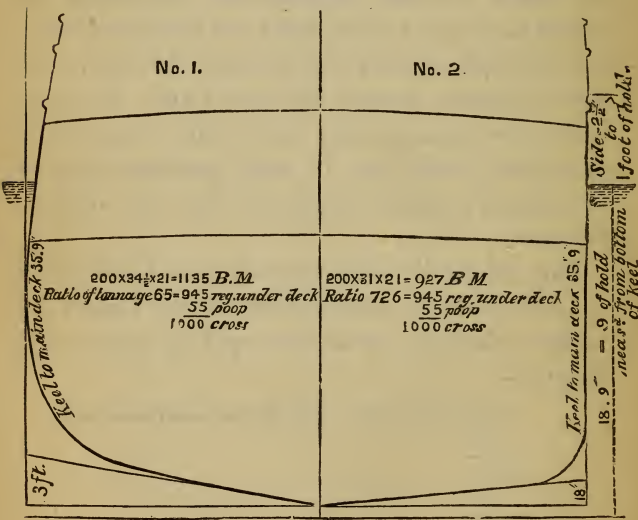
·6

÷ 100)848(70

The following figures will explain how the same dimensions can be made to vary about 300 tons, as previously stated, on the same depth, and nearly 500 tons between 20 feet and 24 feet hold: $205 \times 34\frac{1}{2} =$ 1,166 builders' measurement any depth:—

By ratio	·55 ..	·6 ..	·65 ..	·7 ..	·75
On 20 ft. hold	778 ..	849 ..	919 ..	990 ..	1,061 tons; and
On 24 ft. hold	934 ..	1,018 .	1,103 ..	1,188 ..	1,273 tons;

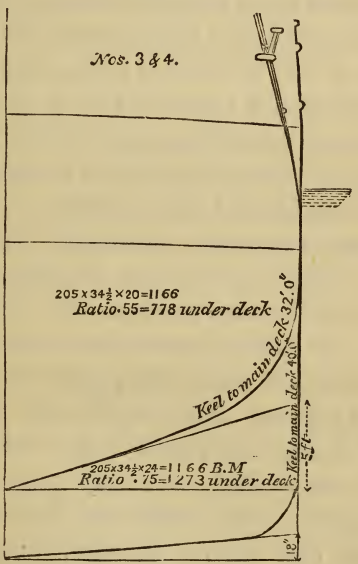
the difference between 778 and 1,061 being 283 tons, and the difference between 934 and 1, 273 being



339 tons on the same depth and varying ratios, and the difference between 778 and 1,273 being 495 tons

on extreme of depths and extreme of ratios, the builders' measurement tonnage being unvarying throughout.

All those tonnages from 778 to 1,061 on the same depth, or from 778 to 1,273 on the varying depths, can be modified in ten tons or one ton by using the ratios from two to four decimal places. There is no


Nos. 3 & 4.
205 x 34½ x 20 = 1166
Ratio .55 = 778 under deck
Keel to main deck 32'0"
Keel to main deck 45'0"
205 x 34½ x 24 = 1166 B.M
Ratio .75 = 1273 under deck
18'

doubt about the varying weights also, as the smallest tonnage can be built on the 700 ton scale, even with

a poop, while the largest and fullest must be built on the 1,200 ton scale, if built to class, and experience on all the ratios has proved them correct weight to tonnage on any form. Referring to diagrams 1, 2, 3, 4, which represent midship sections of sailing vessels:—3 and 4 show the difference of midship form of the limits ·55 and ·75 on the same length, breadth, and builders' measurement (the ratio of middle section below load line being as ratio of displacement + ·25; thus ratio, tonnage ·65; displacement, ·61 + ·25; ·86 ratio of mid-section), but with the depth 20 feet in one and 24 feet in the other, the circumference of half frame in the small vessel is 32 feet, and in the large vessel 40 feet to main deck. Of course the plating and other details of the hull are in the same proportion, scantlings varying as the tonnage. Sections 1 and 2 show the difference of form and ratios for the same tonnage. No. 1 is 200 × 34½ × 21 = 1,135 builders' measurement, ratio ·65 = 945 new measurement under deck, and with poop 1,000 tons gross register. No. 2 is 200 × 31 × 21 = 927 builders' measurement, ratio ·725 = 945 new measurement under deck, and with poop 1,000 tons gross register. Both vessels are the same length and depth and register tonnage; they differ by 3½ feet beam and 208 tons builders' measurement. They must be built on the same line to class, and the narrow vessel has 1 foot 6 inches longer midship frame than the broad vessel, 1 foot 6 inches more

circumference for plating, &c., &c., and the vessels take precisely the same quantities of iron, wood, and all other material. Yet many builders would have no objection to build the latter at an ordinary rate per builders' measurement, and give over 70 tons register in addition, while very few would be willing to build the former at any rate less per builders' measurement with register 135 tons less. I would prefer the register in both cases, and the former or broad ship from choice, as a very superior ship to build and to own.

The following table of eight sailing ships of 1,000 to 1,500 tons intermediate sizes and ratios of tonnage from ·65 to ·74 is a sample of the relation of the constant of weight to register of tonnage, the vessels having been built by four different builders, and all different models. I give the weights as I got them :—

Length.	Breadth.	Depth of hold.	B.M	Register N.M.			Ratio of form under deck.	Class.	Tons of iron invoked.	Constant to gross reg.	Weight complete for sea.	Constant complete to reg.
				Under deck.	Above deck.	Gross.						
190	33·5	21·5	1014	952	42	994	·695	12 A 1	553	·55	771	·775
195	34·5	21·25	1104	961	33	994	·672	Do.	588	·59	771	·775
200	32	21·5	985	958	36	994	·696	Do.	597	·6	774	·777
200	34·5	21	1135	943	56	999	·65	Do.	590	·59	775	·775
200*	33·7	22·5	1090	1111	60	1171	·732	Do.	784	·67	975	·833
208	34·5	23	1186	1121	77	1198	·681	Do. New rls.	715	·595	928	·775
205	35	22·5	1198	1142	82	1224	·707	A A 1	681	·557	924	·735
224	37·5	24·75	1507	1462	63	1525	·707	Do.	910	·6	1120	·735

* The fullest vessel is extravagantly heavy, being nearly 100 tons in excess of all classes in iron and other material.

That the constants apply to steamers as well as to sailing vessels is shown by the following table of eight screw steamers from 100 to 1,500 tons, built between 1855 and 1862 during several changes of Lloyd's rules :—

Length.	Breadth.	Depth of hold.	B.M.	Register N.M.			Ratio under deck.	Class.	Tons of iron invoiced.	Constant to gross reg.	Weight complete.	Constant complete.
				Under deck.	Above deck.	Gross.						
120	18·5	9·5	200	133	5	138	·63	9 yrs.	81	·59	96	·7
145	22	12	339	260	3	263	·68	Do.	152	·58	179	·68
160	24	12	446	325	19	333	·705	Do.	193	·58	226	·68
180	26	13	591	362	42	404	·60	Do.	242	·60	303*	·75
214	28	16	822	604	91	695	·63	12 yrs.	430	·62	500	·72
					55	House			Hull & poop.			
220	26	17	734	660	30	745	·678	9 yrs.	400	·58	491	·66
					66	House						
250	30	21	1110	1059	44	1170	·666	Do. (1855)	661	·6	795	·68
255	36	22	1600	1384	39	1423	·685	12 yrs.	853	·6	995	·7

The variation in constants is due entirely to extras in construction and equipment, the class being true constants. The iron columns in these tables must be understood to mean only the hull iron proper, including masts of iron, but exclusive of smith work, bolts, and nails.

As a further illustration of the accuracy of the constants of weight, irrespectively of dimensions, the following details of two vessels will show—the one a screw steamer ten beams length, the other a sailing ship of less than six beams length :—

* Extra for cattle trade.

S.S. 340 × 34 × 24. Gross 2,100 n.m. Register under Deck, 1,890.

Keel, stern, stern-posts, and rudder		24
Angle iron	355 tons.	
Beams	62 „	
Floors, stringers, ties, keelsons, &c., plates	177 „	
		594
Hull plates		450
		1,068

Ship 200 × 34·5 × 21. Gross, 1,000 n.m. Register under Deck, 943.

Keel, stern, stern-post, and rudder		11
Angle iron	149 tons.	
Beams	41 „	
Floors, &c.	102 „	
		292
Hull plates		215
		518

I purposely omit the small details of straps, slips, rivets, &c., and the material exclusively pertaining to steam vessels, and arrangements for machinery. The latter, with additional bulkheads, usually increase the ironwork of steamers 4 per cent. of tonnage over sailing vessels. Each item in these quantities is not necessary in exact ratio; it is only in the sum totals, and justly so, that the equality of the ratio of weight to tonnage is apparent; my object in the foregoing comparison of weight and length being to show that in all the material dependent on length, form, and tonnage for classification, Lloyd's rules are nearly uniformly constant to register tonnage,

independently of dimensions, from 100 to 2,000 tons.*

It will be apparent from the tables and foregoing remarks that the constants of weight are very nearly as follow:—

Class. Late Rule.	Gross Reg.	Iron.	Finished Weight of Ship.
Sailing Ships, 12 years	1,000	·59	·775
„ A A 1	1,000	·55	·735

If built to Liverpool rule twenty years, in addition to Lloyd's, the increase of material in very full vessels of large tonnage and small dimensions is slight, from one to two per cent. in excess of Lloyd's; but in case of fine vessels of large dimensions to tonnage, the increase of material is very important, amounting in several vessels we have lately built to about three per cent. of tonnage. As this involves an increase of cost from 5s. to 10s. per ton, it is virtually a tax

* Since reading this paper, I have been favoured by Messrs. Gourlay Brothers, Dundee, with particulars of a few of their vessels built to class, which further prove the constants correct. Here is the table:—

Length.	Breadth.	Depth of hold.	B.M.	Register N.M.			Ratio under deck.	Class.	Tons of iron invoiced.	Constant to gross reg.	Weight complete.	Constant to gross reg.
				Under deck.	Above deck.	Gross.						
s.s.230	29	16·40	950	635·30	96·12	781·42	·626	A A 1	469	.6	539	·69
„ 216	28	16·25	830	601·78	90·59	692·37	·612	Do.	407	·59	477	·69
„ 208	28	16·45	797	569 90	94·48	664·38	·595	2 A 1	396	·6	478	·72
„ 216	27	15·45	774	531·02	78·62	609·64	·588	9 A 1	360	·59	414	·68
„ 144	20·75	9·46	801	186·42	20·3	216·72	·66	Do.	127	·61	150	·72
shp170	28	18·8	639	603·8	...	603·8	·675	12 A 1	350	·58	470	·778

These weights do not include forgings, but they include masts and deck house framing.

on fine forms, not only to what they cost in construction, but to what they are obliged to carry of unnecessary weight. The Liverpool rules do not acknowledge the value of thickness of outside plating over five-eighths, stringers and keelsons being of the first importance. Lloyd's rules consider plating of the first importance, and the conflicting interests with owners who require both, necessarily increase the expense of construction.

Screw steamers' constants on the late rules were—

Class.	Gross Reg.	Iron.	Finished Weight.
12 years	1,000	·62	·72
9 „	1,000	·58	·68
6 „	1,000	·54	·64

Under the new rules Aa and Ab, the constants are nearly the same as nine and six years for minimum dimensions, say, length = 10 depths, &c., increasing by easy percentages to twelve and nine years' constants, at extreme dimensions; say, length = 20 depths. This, it must be understood, arises solely from extra material, as a vessel of 20 depths long is not per rule heavier than a vessel of 10 depths of the same tonnage.

The preceding tabulated statements show at a glance the weight of iron as invoiced, and must prove of great assistance to the naval architect in estimating and checking calculations that may be required from time to time.

CHAINS AND ANCHORS FOR SAILING VESSELS.

MINIMUM WEIGHTS (EX. STOCK) OF ANCHORS, SIZES AND LENGTHS OF CHAINS CABLES, AND THE PROOF STRAIN TO WHICH THEY ARE TO BE TESTED, AND THE SIZES AND LENGTHS OF HAWSERS AND WARPS, ACCORDING TO LLOYD'S REGISTER.

Ship's tonnage	Anchors. Number. Bowers.	Number. Stream.	Number. Kedges.	Weight. Bowers. (*a*) Ex. Stock.	Weight. Bowers. (*a*) Adm. Test.	Weight. Including Stock. Stream	Kedge.	Second Kedge.	Stud-chain Cables. (*b*) Minim. Size.	Proved to Adm. Test.	Length.	Hawsers and Warps. Stream. Chain.	Stream. Rope.	Hawser.	Warp.	Length.	Ship's tonnage.
tons.				cwts.	tons.	cwts.	cwts.	cwts.	inch. (*c*)	tons.	fathoms		inch.	inch.	inch.		tons.
50	2	1	1	$2\frac{1}{4}$	$4\frac{7}{10}$	1	$\frac{1}{4}$	..	$\frac{11}{16}$	$8\frac{1}{2}$	120	$\frac{7}{16}$	5	3	..		50
75	2	1	1	$2\frac{3}{4}$	$5\frac{2}{10}$	$1\frac{1}{2}$	$\frac{3}{4}$	..	$\frac{12}{16}$	$10\frac{1}{10}$	120	$\frac{7}{16}$	5	3	..		75
100	2	1	1	4	$6\frac{4}{10}$	$1\frac{3}{4}$	1	..	$\frac{13}{16}$	$11\frac{9}{10}$	150	$\frac{8}{16}$	$5\frac{1}{2}$	3	..		100
125	2	1	1	$5\frac{1}{4}$	$7\frac{6}{10}$	2	1	..	$\frac{14}{16}$	$13\frac{3}{4}$	180	$\frac{8}{16}$	$5\frac{1}{2}$	$3\frac{1}{2}$	..		125
150	2	1	1	6	$8\frac{2}{10}$	$2\frac{1}{2}$	$1\frac{1}{4}$	..	$\frac{15}{16}$	$15\frac{4}{10}$	180	$\frac{9}{16}$	6	4	..		150
175	2	1	1	$7\frac{1}{4}$	$9\frac{5}{10}$	$2\frac{3}{4}$	$1\frac{1}{4}$	..	1	18	180	$\frac{9}{16}$	6	4	..		175
200	3	1	1	$8\frac{1}{4}$	$10\frac{4}{10}$	3	$1\frac{1}{2}$	..	$1\frac{1}{16}$	$20\frac{3}{10}$	180	$\frac{10}{16}$	$6\frac{1}{2}$	4	..		200
250	3	1	2	10	12	$4\frac{3}{4}$	$2\frac{1}{4}$	1	$1\frac{2}{16}$	$22\frac{3}{4}$	210	$\frac{10}{16}$	7	5	..		250
300	3	1	2	12	$13\frac{9}{10}$	5	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{16}$	$25\frac{1}{10}$	210	$\frac{11}{16}$	$7\frac{1}{2}$	$5\frac{1}{2}$	..		300
350	3	1	2	$13\frac{1}{2}$	$15\frac{2}{10}$	6	3	$1\frac{1}{2}$	$1\frac{4}{16}$	$28\frac{1}{10}$	240	$\frac{11}{16}$	$7\frac{1}{2}$	$5\frac{1}{2}$	..		350
400	3	1	2	$15\frac{1}{4}$	$16\frac{7}{10}$	$6\frac{1}{2}$	$3\frac{1}{4}$	$1\frac{3}{4}$	$1\frac{5}{16}$	31	240	$\frac{12}{16}$	8	6	..		400
450	3	1	2	$16\frac{3}{4}$	18	7	$3\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{6}{16}$	34	270	$\frac{12}{16}$	$8\frac{1}{2}$	$6\frac{1}{2}$	..		450
500	3	1	2	18	19	8	4	2	$1\frac{7}{16}$	$37\frac{2}{10}$	270	$\frac{13}{16}$	9	7	..		500
600	3	1	2	21	$21\frac{6}{10}$	9	$4\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{8}{16}$	$40\frac{1}{2}$	270	$\frac{13}{16}$	$9\frac{1}{2}$	7	4		600
700	3	1	2	$23\frac{1}{2}$	$23\frac{6}{10}$	10	5	$2\frac{1}{2}$	$1\frac{9}{16}$	44	300	$\frac{14}{16}$	10	8	5		700
800	3	1	2	$25\frac{1}{2}$	$25\frac{2}{10}$	$10\frac{1}{2}$	$5\frac{1}{4}$	$2\frac{3}{4}$	$1\frac{10}{16}$	$47\frac{1}{2}$	300	$\frac{14}{16}$	10	8	5		800
900	3	1	2	$27\frac{3}{4}$	$26\frac{9}{10}$	11	$5\frac{1}{2}$	$2\frac{3}{4}$	$1\frac{11}{16}$	$51\frac{2}{10}$	300	$\frac{15}{16}$	10	9	$5\frac{1}{2}$		900
1,000	3	1	2	30	$28\frac{6}{10}$	12	6	3	$1\frac{12}{16}$	$55\frac{1}{10}$	300	$\frac{16}{16}$	10	9	$5\frac{1}{2}$		1,000
1,200	3	1	2	32	$30\frac{1}{10}$	13	$6\frac{1}{2}$	$3\frac{1}{4}$	$1\frac{13}{16}$	$59\frac{1}{10}$	300	1	10	$9\frac{1}{2}$	6		1,200
1,400	3	1	2	34	$31\frac{6}{10}$	$13\frac{1}{2}$	$6\frac{3}{4}$	$3\frac{1}{4}$	$1\frac{14}{16}$	$63\frac{1}{4}$	300	1	10	10	6		1,400
1,600	3	1	2	$36\frac{1}{2}$	$33\frac{4}{10}$	14	7	$3\frac{1}{2}$	$1\frac{15}{16}$	$67\frac{1}{2}$	300	$1\frac{1}{16}$	11	$10\frac{1}{2}$	$6\frac{1}{2}$	The length of them to be 90 fathoms each.	1,600
1,800	3	1	2	38	$34\frac{5}{10}$	$14\frac{1}{2}$	$7\frac{1}{4}$	$3\frac{3}{4}$	2	72	300	$1\frac{1}{16}$	11	11	7		1,800
2,000	4	1	2	40	$35\frac{1}{10}$	15	$7\frac{1}{2}$	$3\frac{3}{4}$	$2\frac{1}{16}$	$76\frac{1}{2}$	300	$1\frac{2}{16}$	11	11	7		2,000
2,500	4	1	2	42	$37\frac{1}{10}$	17	$8\frac{1}{2}$	$4\frac{1}{4}$	$2\frac{1}{8}$	$81\frac{3}{10}$	330	$1\frac{2}{16}$	12	12	8		2,500
3,000	4	1	2	45	$39\frac{2}{10}$	19	$9\frac{1}{2}$	$4\frac{1}{4}$	$2\frac{1}{8}$	$91\frac{1}{10}$	360	$1\frac{3}{16}$	12	12	8		3,000

Notes to preceding Table.

Mem.—For steamers the anchors and cables will not be required to exceed in weight and length those of a sailing vessel of two-thirds their tonnage.

(*a*) Two of the bower anchors must not be less than the weight set forth, but in the third a reduction of 15 per cent. will be allowed. All anchor stocks must be of acknowledged and approved description.

(*b*) Unstudded close-link chains of 1 inch in diameter and under will be admitted as cables, if proved to two-thirds the test required for stud-chains; but in all such cases a short length, not less than twelve links, must be tested up to the full strain for stud-link chains.

(*c*) Parties desirous of using or supplying chains of a smaller size, and who are willing to submit them to a greater strain than set forth, may submit their propositions to the committee.

Round Wire Ropes for Ship's Standing Rigging, etc.

Hemp.	Iron.		Steel.		Strength.	
Circumference.	Circumference.	lbs. weight per fathom.	Circumference.	lbs. weight per fathom.	Working Load. Cwts.	Breaking Strain. Tons.
2¾	1	1	..	..	6	2
..	1½	1½	1	1	9	3
3¾	1⅝	2	..	..	12	4
..	1¾	2½	1½	1½	15	5
4½	1⅞	3	..	..	18	6
..	2	3½	1⅝	2	21	7
5½	2⅛	4	1¾	2½	24	8
..	2¼	4½	..	..	27	9
6	2⅜	5	1⅞	3	30	10
..	2½	5½	..	..	33	11
6½	2⅝	6	2	3½	36	12
..	2¾	6½	2⅛	4	39	13
7	2⅞	7	2¼	4½	42	14
..	3	7½	..	..	45	15
7½	3⅛	8	2⅜	5	48	16
..	3¼	8½	..	..	51	17
8	3⅜	9	2½	5½	54	18
..	3½	10	2⅝	6	60	20
8½	3⅝	11	2¾	6½	66	22
..	3¾	12	..	..	72	24
9½	3⅞	13	3¼	8	78	26
10	4	14	..	..	84	28
..	4¼	15	3⅜	9	90	30
11	4⅜	16	..	..	96	32
..	4½	18	3½	10	108	36
12	4⅝	20	3¾	12	120	40

The steel ropes are of equivalent strength.
Hemp ropes of equal strength.

LAND ENGINES.

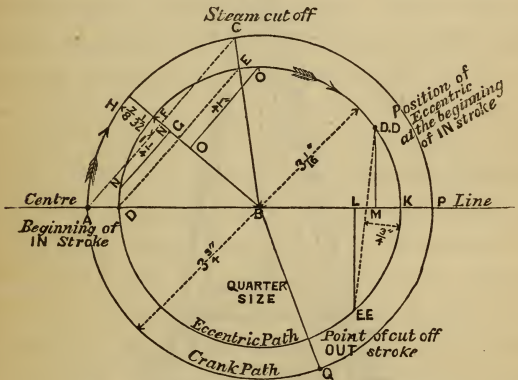
HIGH-PRESSURE HORIZONTAL LAND ENGINES.

There is no recognised rule for the nominal horse-power of this class of engine. However, I calculate the diameter of cylinder thus:—Taking the steam in boiler as 30 lbs., and speed of piston, say 200 feet per minute for a 20 horse-power engine, make an allowance of five-eighths more, or 32·5 horse-power; now, by the same formula as for marine engines: — $\frac{33000}{200 \times 30} = 5{\cdot}5$ square inches; that multiplied by $32{\cdot}5 = 178{\cdot}75 = 15$ inches diameter nearly, having a stroke of 24 inches. For heavy engines of this description the author strongly recommends a small cylinder, with pinion on engine-shaft, gearing into a spur-wheel for the machinery, more especially for the colonies, so as to be easily transported. This arrangement, running at a high piston-speed and great steam-pressure, will prove as good an engine, and the first cost be much less.

THE CRANK AND ECCENTRIC PATH DELINEATED.

In all cases, with a proper length of eccentric rod, the versed sine of the chord, described by the eccentric path, equals for all practical purposes the opening of the valve, *minus* one-half of the lead. The outside circle denotes the path of crank, while the inner circle is the path of eccentric. A B is the

line of crank, at the beginning of the IN-stroke, and B C the line of cut-off; it is very evident that the point A, or crank-pin, travels from A to C, while that of the eccentric travels from D to E; the versed sine, H I, is, say $\frac{7}{8}$ $\frac{1}{32}$ inches, while the versed sine, F G, is three-quarters of an inch; the full opening, by valve, equals 1 inch, and the lead, say half an inch. For sake of illustration, on each side of the



The Crank and Eccentric Path delineated.

line D E set off one-quarter of an inch, or one-half of the lead; draw lines, N N and O O, parallel thereto; N N may be termed the line of lead, and O O the line of cut-off. As the valve must open and shut while the crank-pin travels from A to C, it is necessary to project these dimensions to the other side of eccentric's path at K, set off the full opening by valve, from K to L, then set back the lead from L to

M; from the points L and M erect perpendiculars, cutting the eccentric path at the points D D and E E; the point D D is the position or lead of valve, when

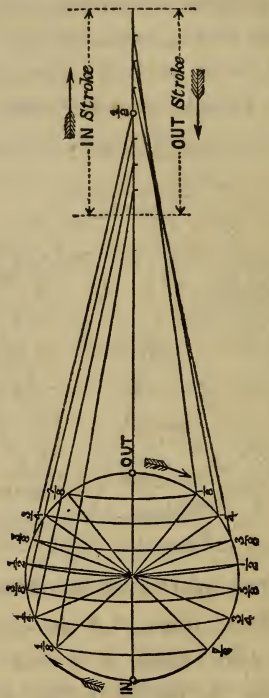


Diagram showing line of cut-off for the IN and OUT Stroke. Length of Connecting-rod 4½ times the Radius of Crank.

the crank-pin is at A; but when the crank-pin has traversed from A to C, the point D D has traversed to E E, in the path of eccentric, when the steam is

cut off; the radius of the eccentric is $3\frac{1}{16}$ inches, and, as L K is 1 inch, B L, or the lap of valve, will be $2\frac{1}{16}$ inches. Now, this just provides for the IN-stroke, the line of cut-off for the OUT-stroke being quite different; it is found by taking the length of connecting-rod, and sweeping from a point measured from P to B, on the centre line (or the given part of the stroke, when the steam is cut off, equal for both IN and OUT), until it cuts the crank path at Q, when great nicety is required. The steam-port must be arranged for the OUT-stroke, as more lap is required, consequently less opening by valve, and the IN-port to be contracted in length, so as to give the same area for both IN and OUT, and the same cut-off. The eccentric-rod, mathematically speaking, is the hypothenuse of a right-angled triangle, in having a radius sweeping from the centre line the points L and E E; this can never be attained. However, the length of eccentric-rod should not be less than six times the travel of valve, or the throw of eccentric. When the versed sine, H I, is given, and the radius of the crank is $3\frac{3}{4}$ inches, and the opening by valve less one-half lead, namely, three-quarters of an inch, the radius of the eccentric can be found by calculation, based on the known property that the versed sines of circles of similar segments are as the diameters of the respective circles. Thus:—

$$7{\cdot}25 : 30 :: 6 = 24{\cdot}6, \text{ or } 3\tfrac{1}{16} \text{ inches full.}$$

HIGH-PRESSURE ENGINES.

General Rules. — For the steam-way, by valve, ports, &c.: Diameter of piston-rod, connecting-rod, crank-shaft, and all minor details—the same rules as for the marine engine, as likewise feed-pump, &c.

The Governor.—Divide 375 by the square root of the pendulum, or the vertical distance from point of suspension to the working plane of the centre of balls, and one-half of the quotient will be the revolutions required. Thus, supposing the vertical height to be 36 inches, square root = 6 :—

$$\frac{375}{6} = 62{\cdot}5 \div 2 = 31{\cdot}2 \text{ revolutions.}$$

The point of suspension should be as near the centre of rotation as possible, and the working angle never exceed 45°; diameter of balls, 4 to 9 inches.

The Fly-wheel.—The velocity of the periphery of fly-wheel should always exceed the velocity of the periphery of the stones of a flour or other mill, to prevent back lash. To find the weight in cwts., multiply the constant 1,366 by the horse-power of the engine, divide the product by the mean diameter of the rim of wheel, multiplied by the number of revolutions per minute, and the quotient will give the weight of the rim in cwts. I will take an example from practice: the diameter of wheel was 22 feet at pitch line (this was for a pair of coupled

engines, 80 horse-power collectively), mean diameter say 21 feet, and 21 revolutions :—

$$\frac{1{,}366 \times 80}{21 \times 21} = 247{\cdot}8 \text{ cwts. weight of rim.}$$

The actual weight of this wheel complete was 14 tons 5 cwts. The rim was of a T section.

To find the thickness of ring, when the area is given in square inches ; suppose the outside diameter to be 22 feet, and the inner circle 19 feet 11 inches in diameter, equals 9,612 square inches area ; divide the weight in pounds, say 27,664, by the area in inches multiplied by ·263, and the quotient is the thickness in inches :—

$$\frac{27{,}664}{(9{,}612 \times {\cdot}263) = 2{,}527{\cdot}9} = 10{\cdot}9, \text{ say 11 inches thick.}$$

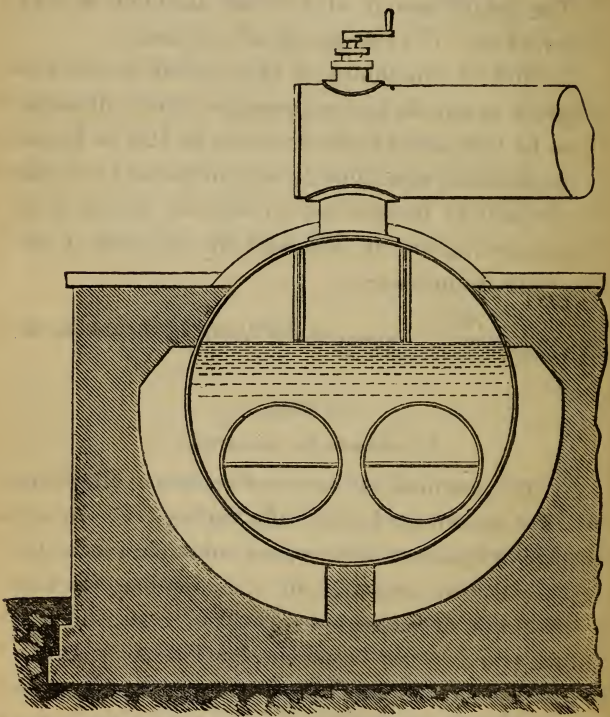
BOILERS.

According to Mr. Armstrong.

To each nominal horse-power make an allowance of "one square yard of heating surface," one square foot of fire-grate surface, and one cubic yard capacity. I will take an example of a double-flue Cornish boiler of 50 horse-power :—The boiler was 35 feet long and 7 feet diameter, the length being in the proportion of 5 to 1 of the diameter ; the furnaces were 2 feet 4 inches in diameter, running quite parallel through and through, with return wheel flues underneath ; the cubic contents are 1,344 feet, or 26·8 cubic feet per horse-power ; the total heating

surface, 953 square feet, or 19 square feet per horse-power; fire-grate surface, 35 square feet, or ·7 square feet per horse-power.

Strength of Boilers.—Taking the breaking strain



Cornish Boiler of 50 Horse-power.—Scale $\frac{1}{4}$-inch = 1 foot.

of the best plates to be 62,544 lbs., and the worst 34,000 lbs., we have a mean of 48,272 lbs.: take

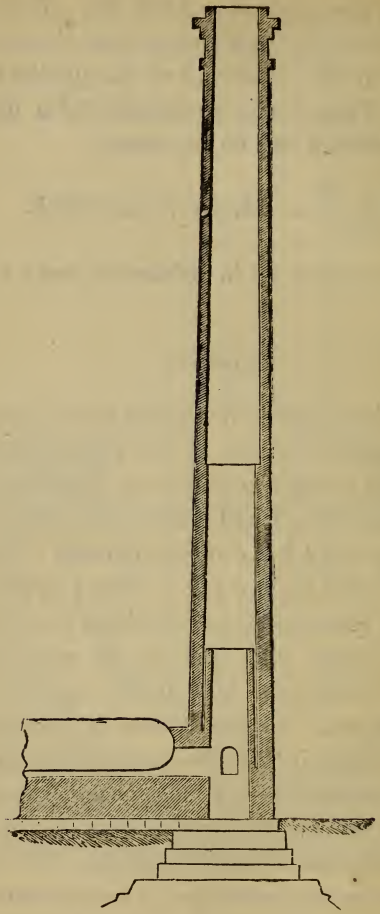
one-sixth as the constant = 8,045 lbs. To find the thickness, multiply the diameter into the pressure, and divide by the constant, and the quotient is the thickness. Thus, I take an example of a boiler 78 inches in diameter and 60 lbs. steam.

$$\frac{78 \times 60}{8045} = \cdot 58, \text{ say } \tfrac{9}{16} \text{ inch thick.}$$

When boilers are set in brickwork more must be allowed.

CHIMNEYS.

Brick chimneys are often made much larger than what is required, owing to the great height they are forced to be constructed, so as to prevent smoke nuisance in towns. I will take an example—a boiler 28 feet long and 4 feet 6 inches diameter; the chimney was 70 feet high, 3 feet 7 inches square inside at bottom; the thickness of the base, one brick and a half for 30 feet high, and for the remainder one brick in thickness, the hole at the top being 3 feet 4 inches square. At the bottom of the inside, for 15 feet in height, it had a fire-brick lining of one-half brick in thickness, with 1 inch space between it and inside of common brickwork, so as to protect the chimney from the action of the flame. The foundation should be deep, resting on a bed of concrete, the depth of the concrete being regulated by the nature of the soil.



Chimney.—Scale $\frac{1}{16}$th of an inch = 1 foot.

PUMPING ENGINES.

The pumping Water out of Floating Docks, &c.—To determine the power required, as likewise to discharge a given quantity of water, I will assume 6,000 tons (equal 35 cubic feet of salt water per ton) as the quantity, to be raised or discharged at a height of, say 30 feet from suction-pipe: time, two hours. Divide the quantity of tons by 2, and then by 60, and that will give the quantity per minute; divide the result by 14·7 tons, equals one horse-power, 1 foot high per minute.

$$
\begin{array}{r}
2)\underline{6{,}000} \\
60)\underline{3{,}000} \\
14{\cdot}7)\underline{50} \\
3{\cdot}4 \text{ horse-power.}
\end{array}
$$

This gives a power to raise 50 tons of sea water 1 foot high. Now $3{\cdot}4 \times 30 = 102$ horse-power; make an allowance of, say one-fifth for friction, say 122 horse-power. If the time to raise or discharge the water was four hours instead of two hours, 61 horse-power would be sufficient. The usual speed of pumps is 160 feet per minute. The height of the pump-bucket at the end of up-stroke should never exceed 30 feet from bottom of suction-pipe.

To find the diameter of pumps that will discharge 11,000 tons of sea-water out of a floating dock—time, say four hours—multiply 11,000 by $35 = 385{,}000$

cubic feet; that divided by $160 \times 60 \times 4 = 38{,}400$ —thus :—

$$\frac{385{,}000}{38{,}400} = 10 \text{ square feet.}$$

As there were eight single-acting pumps, this divided by 4 will give the area in square feet of each pump: $10 \div 4 = 2{\cdot}5$, equal, say 20 inches in diameter, as adopted in floating dock, as before described.

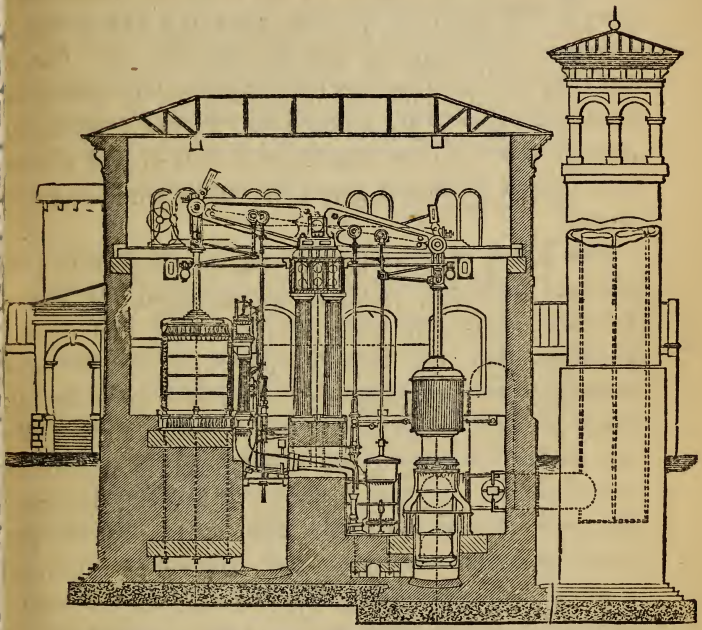
Weight of a cubic foot of water	= 62·5 lbs.	avoirdupois.
Weight of a cubic inch	= ·03617	„
Weight of a column of water 12 inches high and 1 inch square	= ·434	„
Weight of a cylindrical foot of water	= 49·1	„
Weight of a cylindrical inch....	= ·02848	„
Weight of a column of water 12 inches high and 1 inch diameter	= ·341	„
11·2 imperial gallons	= 1 cwt.	
224 imperial gallons	= 1 ton.	
1·8 cubic feet of water	= 1 cwt.	
35·84 cubic feet	= 1 ton.	
1 cubic foot	= $6\frac{1}{4}$ imperial gallons.	
1 cylindrical foot.....	= 5	„

POWER REQUIRED TO RAISE WATER FROM WELLS.

Diameter of pump.	Quantity of water raised per hour.	Maximum depth raised by each unit of power.			
		One man turning a crank.	One donkey working a gin.	One horse working a gin.	One-horse steam engine.
in.	gallons.	feet.	feet.	feet.	feet.
2	225	80	160	560	880
$2\frac{1}{2}$	360	50	100	350	550
3	520	35	70	245	385
$3\frac{1}{2}$	700	25	50	175	275
4	900	20	40	140	220

SINGLE-ACTING PUMPING ENGINE

At the East London Waterworks at Lea Bridge.



When this engine was erected in 1855 it was the largest of its class in the metropolis, the cylinder being 100 inches in diameter, having a stroke of 11 feet—the pump, of the plunger type, 50 inches in diameter, having the same length of stroke as steam-piston, namely, 11 feet. When working full power, it pumps about 9,000 gallons per minute, usually

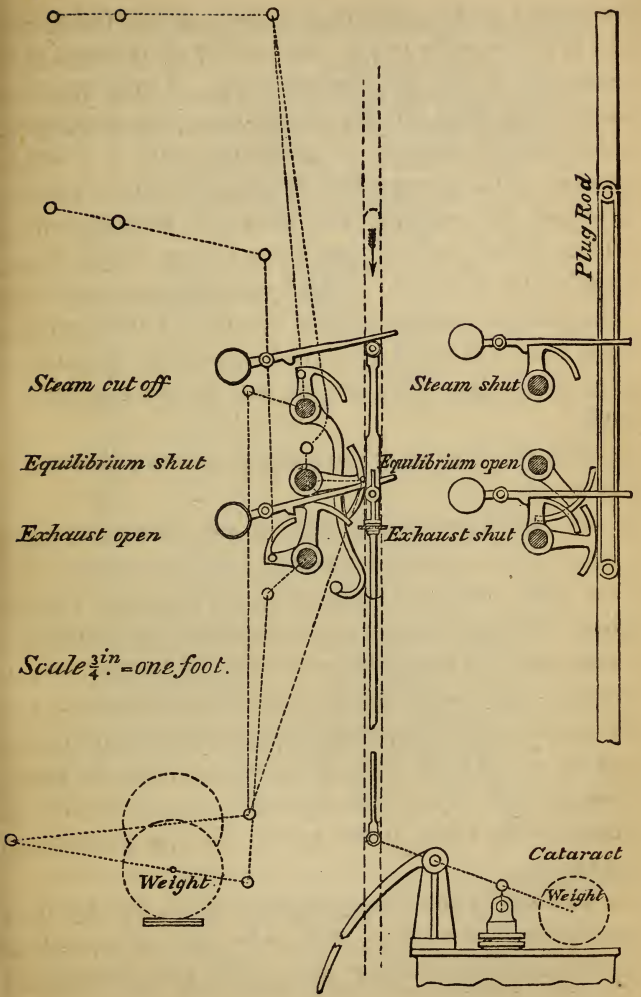
140 feet high, which water is conveyed into London by cast-iron pipes 36 inches in diameter. In 1858 an engine was erected for the Vauxhall Water Company at Battersea, the cylinder being 112 inches in diameter, weighing, with its case, 36 tons. Out of 115,000,000 gallons pumped daily for the metropolis 79,000,000 gallons are pumped by the single-acting engine. Some of these engines have worked without intermission for twenty years, the repairs being very slight.

The action of the single-acting engine is quite different from reciprocating arrangements, having fly-wheel shaft, connecting-rod, &c. And there is no doubt that the Cornish engine is the most economical working engine, due entirely to the high steam-pressure used, and the facility of cutting off at any part of the stroke that is found best under the circumstances. Cornish engineers do all they can to economise fuel, by the careful clothing of the parts where radiation takes place, the cylinder having a steam-jacket, covered with felt and wood overall, as likewise the steam-pipes, and the tops of boilers are covered with fire-bricks, ashes, &c., so as thoroughly to protect them from the cold. As will be seen from the drawing, the cylinder is at one end of the beam, and the pump at the other; on the top of the plunger for pump, a heavy weight is placed. The whole power of the engine is expended in raising this weight along with the plunger, and the water is simply

forced by the beam being loaded at the pump end. What the accumulator is to the water-crane, this load on the end of the beam is to the water-works' engine: each produces pressure or hydrostatic head. The valve-gear is somewhat complicated; the valves are of the equilibrium type. Two valves are fitted to the top chest; first the steam-valve, for allowing the steam on top of piston; secondly, the equilibrium, to the under side of piston; and, thirdly, the exhaust-valve, fitted to the valve-chest at the bottom of cylinder. There are three cross-shafts, arranged vertically, one for the steam, equilibrium, and exhaust valves respectively; the top one is for the steam-valve, the middle one for the equilibrium, and the bottom one for the exhaust. There is an arm keyed on each shaft, having a rod and weight at the end; those weights lift the respective valves, and they are shut with the tappets, on the plug-rod acting or sliding against handles keyed on each shaft, the tappet, or sliding-bar for the steam-valve, being a long, wrought-iron, parallel bar. This is required, as the steam may be cut off at one-fourth of the stroke; consequently, the bar would require to be somewhat more than three-fourths of the length of stroke of plug-rod, so as to keep the steam-valve shut. The two other tappets are simply round arms with leather washers, having eyes for plug-rod passing through, and are simply fixed with a set screw. On the steam and exhaust shafts there is

fitted a catch and pall for each, keeping the valves shut until released by the cataract, which is simply a pump worked by the down-stroke of plug-rod, having a weight so arranged that the oil or water is forced out of pump: the delivery is regulated by a valve or cock. On the end of weight-lever there is an adjustable rod passing upwards for raising the palls, thus freeing the catches, and the weight-arm instantly lifts the valve. To keep the equilibrium-valve shut, there is a quadrant keyed on middle and bottom shaft, so that when the exhaust-valve is open the top quadrant abuts on the lower one, thus keeping the equilibrium-valve shut until it is released, when the tappet on bottom shuts off the exhaust, and allows the quadrant to pass the equilibrium-quadrant, thus releasing it, and the valve is instantly opened with the weight-arm.

Now we will suppose the piston at the top of the stroke, and the exhaust-valve full open, caused by the cataract releasing the bottom catch; the cataract-rod, still moving upwards, releases the top catch, and the steam-valve is instantly raised by the weight-arm; the piston at once descends, until the long parallel tappet cuts off the steam; the plug-rod still moves on until the tappet shuts the exhaust at the end of piston-stroke. And as the equilibrium-valve was held in position by its quadrant, at the moment the exhaust is shut, the equilibrium-valve opens; so the steam is simply allowed to escape from the top


Plug Rod
Steam cut off
Steam shut
Equilibrium shut
Equilibrium open
Exhaust open
Exhaust shut
Scale $\frac{3}{4}$in. = one foot.
Weight
Cataract
Weight

of piston to the bottom, the speed the loaded end of beam descends being regulated by the amount of opening of the equilibrium-valve. The plug-rod ascending shuts off the equilibrium, thus stopping the further descent, or producing only a slight motion of the plunger and weight, until the cataract releases the exhaust, and then the steam-valves. Thus it will be seen that for a part of the down-stroke the steam and exhaust valves are open, while the exhaust remains so until the end of the stroke, and then it is closed, while in the up-stroke of piston the equilibrium-valve is open, and all the rest shut off.

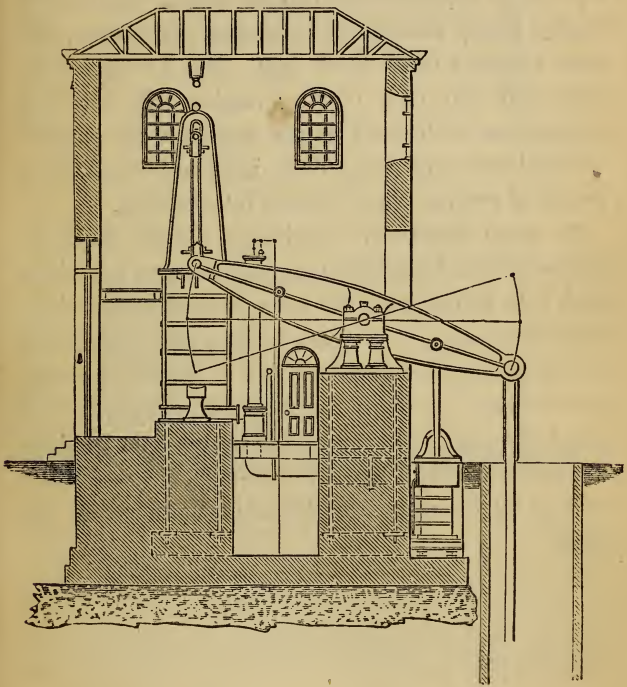
The drawings show the gear in the two different positions.

The arrangements for colliery and mine pumping engines are somewhat similar; however, instead of the main centre of beam being supported by cast-iron columns, the engine-house terminates at the main centre, and the beam pillow-block rests on a strong wall, carried up from the foundation; the outer weight is done away with, the pump-rods being simply attached to the end of beam with wrought-iron straps, having brasses and keys. This arrangement requires the beam to be made in two halves, with the gudgeons between.

To simplify the mine-pumping engine, side levers are sometimes adopted, with side rods, cross-head, and guides, thus doing away with the expensive

parallel motion, as likewise reducing the height of lever wall.

All direct-acting pumping engines are provided with spring beams, so as to cushion the shock, should



Single-acting Side-lever Pumping Engine, erected at the Duke of Buccleuch's Colliery, by Dalkeith.

160 H. P.

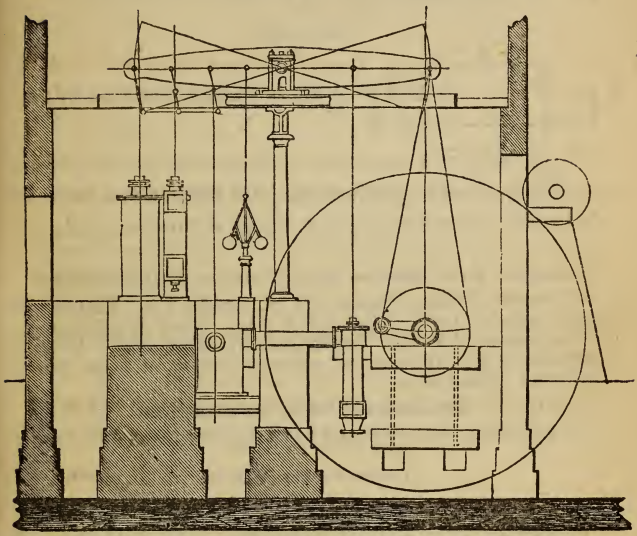
the gear get out of order, or miss a stroke. However, in good arrangements this is a rare occurrence.

For pumping sewage I consider the Cornish engine admirably suited, although rotative engines have been adopted. Where the sewage is not forced to any great height, rotative engines will be found to answer, as more strokes can be given, the Cornish engine rarely exceeding 12 strokes per minute, and even in some cases much less. But I consider the wear and tear of a rotative engine will not bear comparison with the Cornish engine, some engines of the latter type doing duty, as before stated, for a period of twenty years without intermission.

In some situations centrifugal pumps could be conveniently adopted for pumping sewage, but where land is to be irrigated the sewage must be forced, in many instances, to a great height, and distributed on the land under pressure. So it becomes imperative to have common force or lift pumps, having stand-pipes for maintaining the hydrostatic head, as likewise fitted with an overflow-pipe, the main-pipe having all the necessary sluices for distributing the fluid.

HIGH AND LOW PRESSURE ENGINES

At the Royal Arsenal Gun Factory, Woolwich.



80 horse-power collectively.

Between centre and centre of engines, 10 ft. 6 in. Diameter of large cylinder, 31 in. × 6 ft. stroke; steam-ports, 12 in. × 3 in. Diameter of small cylinder, 15½ × 4 ft. 6 in.; steam-ports, 12 in. × 2 in. Diameter of crank-shaft (cast iron) at journals, 10 in. × 15 in. long. Diameter of crank-pins, 5½ in. × 7½ in. long. Diameter of air-pump, 21 in.; stroke, 3 ft. Diameter of fly-wheel, 22 ft. at pitch-line; teeth, 12 in. broad, and 3 in. pitch. Diameter of pinion, 4 ft. 6 in.

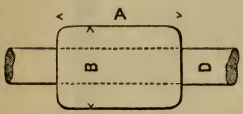
Speed of engine.....	21	revolutions.
,, second shaft	102	,,
,, third shaft	150	,,

The shafting tapering in parallel lengths from 8 in. for pinion to 3 ins. at end; total length of shafting being about 932 ft.; weight of shafting, 18 tons 18 cwt.

Three Boilers.

35 ft. long × 7 ft. diameter, with two inside furnaces 2 ft. 6 in. diameter, with return wheel flues. Shell, $\frac{1}{2}$ in. thick; ends, $\frac{5}{8}$ in. thick; flues, $\frac{3}{8}$ in. thick; rivets, $\frac{3}{4}$ in. thick.

Couplings.



A equals diameter, multiplied by 3·6.
B „ „ 2·4.

When of an extra size, this proportion can be reduced, and wrought-iron rings shrunk on ends.

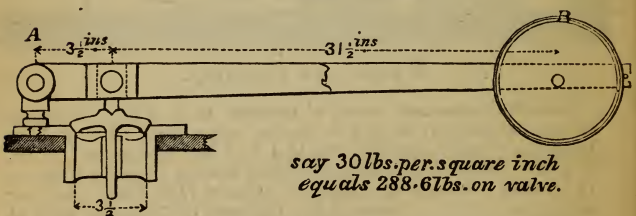
High and Low Pressure Beam Engine of 30 Horse-power.

Diameter of large cylinder, $28\frac{1}{4}$ in.; stroke, 5 ft. Diameter of small cylinder, $14\frac{1}{8}$ in.; stroke, 3 ft. 9 in. Diameter of air-pump, 21 in.; stroke, 2 ft. 6 in. Diameter of fly-wheel, 16 ft.; diameter of shaft, $9\frac{1}{2}$ in. Diameter of pinion, 3 ft. 6 in. × 10 in. broad. Diameter of shaft, 5 in.

Revolutions of engine per minute, 24.

Two boilers, 28 ft. long, and 6 feet diameter; flue, 3 ft. 8 in.

Lever Safety Valves.



The distance on length of A B 35 inches, and A C $3\frac{1}{2}$ inches.

$$\frac{288{\cdot}6 \times 3{\cdot}5}{A\,B = 35} = \text{weight on B} = \text{say, } 28{\cdot}86 \text{ lbs.}$$

$$\frac{288{\cdot}6 \times 3{\cdot}5}{B = 28{\cdot}86} = \text{B from A} = \text{say, } 35 \text{ inches.}$$

$$\frac{28{\cdot}86 \times 35}{A\,C = 3{\cdot}5} = \text{total pressure on valve} = 288{\cdot}6 \text{ lbs.}$$

When great nicety is required, subtract the weight of valve, and the effective leverage, or weight of lever, from 288·6, the total (steam lb.) pressure on valve.

RULES FOR BEAM ENGINES.

The length of beam should not be less than three times the stroke, and its breadth one-half of the stroke; for breadth at ends, multiply the breadth at middle by ·4. To find the thickness of web at centre, multiply the total pressure on the piston by one-half of the length of beam in inches, divide the result by the constant 500 into the depth in inches, and the quotient is the sectional area in square inches. Thus, a cylinder having a total pressure of 22,620 on piston, length of half-beam 106 inches, depth of beam 36 inches:—

$$\frac{22{,}620 \times 106}{500 \times 36} = 133 \div 36 = 3{\cdot}6 \text{ thick at centre;}$$

and at the ends or web $\frac{3{\cdot}6}{1{\cdot}5} = 2{\cdot}4$ inches thick.

Diameter of main-centre gudgeon one-fourth of cylinder's diameter.
" " piston-rod gudgeon, 6·5 " "
" " crank-pin gudgeon, 5·5 " "
Length of crank-pin, one-third more than diameter.

All the wrought-iron rods, &c., can be calculated according to the strain, 2,240 lbs. per square inch for compressive strain, and 4,000 lbs. for tensional strain.

The air-pump has generally a stroke of half beam.

To find the contents, divide the cubic contents of steam-cylinder by 4·3.

Condenser should be of about twice the capacity of air-pump.

COLD-WATER PUMP.

To find the diameter of pump, multiply the constant 2,200 by the horse-power, divide by the stroke of pump in inches into the number of strokes per minute, and the square root of the quotient equals the diameter of pump in inches; thus, for 40 horse-power, with a stroke of pump 36 inches, number of strokes 21—

$$\frac{2{,}200 \times 40}{36 \times 21} = \sqrt{116} = 10\tfrac{3}{4} \text{ in. diameter.}$$

FEED PUMP.

Same rule as for the marine engine.

CAST-IRON CRANKS.

Depth of large eye equals the diameter of shaft; thickness of metal round eye equals half of shaft; depth of crank-pin top equals $1\frac{3}{4}$ the diameter of pin; thickness equals $\frac{5}{8}$ of pin; main web equals one-half of shaft in thickness.

MISCELLANEOUS.

TEETH OF WHEELS.

To find the thickness of tooth, the strain at the pitch-line being given—divide the pressure in pounds at the pitch-line by 3,000, and the square root of the quotient is the thickness of the tooth in inches, the breadth being 2·5 times the pitch.

To find the horse-power that may be transmitted by wheel, multiply the square of the pitch in inches by the breadth of tooth and velocity in feet per second at the pitch-line, and divide the result by 9, and that will give the actual horse-power—or by 16 will give the nominal horse-power. If the pitch of a cast-iron wheel be 1, brass = 1·12, and cogged wheels = 1·26.

PROPORTIONS.

From pitch-line to top of tooth	=	pitch	× 0·33
Total depth of tooth	=	„	× 0·75
Thickness of rim of wheel	=	„	× 0·45
Thickness of arms	=	„	× 0·45
Ordinary width of tooth.....	=	„	× 2·5

Weight of 1 Foot of Tapered Angle Iron.

The thickness measured at point. Equal sides.

Size.	Thickness.	Weight.			Size.	Thickness.	Weight.		
in.	in.	lbs.	oz.	dr.	in.	in.	lbs.	oz.	dr.
1	$\frac{3}{16}$	1	2	2	$2\frac{1}{4}$	$\frac{6}{16}$	3	0	12
$1\frac{1}{8}$	$\frac{1}{8}$	0	15	6	$2\frac{3}{8}$	$\frac{3}{8}$	5	8	12
$1\frac{1}{4}$	$\frac{1}{8}$	1	15	12	$2\frac{1}{2}$	$\frac{1}{4}$	4	9	8
$1\frac{1}{4}$	$\frac{1}{8}$	1	1	6	$2\frac{1}{2}$	$\frac{5}{16}$	5	0	12
$1\frac{1}{4}$	$\frac{3}{16}$	1	9	4	$2\frac{1}{2}$	$\frac{3}{8}$	6	9	10
$1\frac{3}{8}$	$\frac{1}{8}$	1	4	8	$2\frac{1}{2}$	$\frac{1}{2}$	7	4	0
$1\frac{3}{8}$	$\frac{3}{16}$	1	10	14	$2\frac{3}{4}$	$\frac{6}{16}$	6	9	4
$1\frac{1}{2}$	$\frac{3}{16}$	2	0	0	$2\frac{3}{4}$	$\frac{3}{8}$	6	12	0
$1\frac{1}{2}$	$\frac{1}{4}$	2	3	14	$2\frac{3}{4}$	$\frac{7}{16}$	7	8	2
$1\frac{3}{4}$	$\frac{1}{8}$	1	13	2	3	$\frac{1}{4}$	5	12	6
$1\frac{3}{4}$	$\frac{1}{4}$	2	8	0	3	$\frac{5}{16}$	6	14	0
$1\frac{3}{4}$	$\frac{3}{8}$	4	4	8	3	$\frac{3}{8}$	7	9	12
2	$\frac{5}{16}$	4	5	6	3	$\frac{7}{16}$	8	14	10
2	$\frac{3}{8}$	4	14	10	3	$\frac{1}{2}$	9	11	8
$2\frac{1}{4}$	$\frac{1}{4}$	2	8	0	$3\frac{1}{2}$	$\frac{7}{16}$	9	13	6

Weight of 1 Foot of Tapered Angle Iron.

The thickness measured at point. Unequal sides.

Size.	Weight.			Size.	Weight.		
in. in. in.	lbs.	oz.	dr.	in. in. in.	lbs	oz.	dr.
$2 \times 1\frac{1}{2} \times \frac{3}{16}$	2	6	0	$3\frac{1}{2} \times 3 \times \frac{3}{8}$	7	10	10
$2\frac{3}{8} \times 1\frac{3}{8} \times \frac{5}{16}$	3	4	10	$3\frac{3}{4} \times 2 \times \frac{5}{16}$	5	14	4
$2\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	2	7	14	$3\frac{3}{4} \times 3 \times \frac{5}{16}$	8	2	10
$2\frac{1}{2} \times 1\frac{1}{4} \times \frac{1}{4}$	3	4	0	$3\frac{7}{8} \times 2\frac{1}{4} \times \frac{1}{4}$	5	5	14
$2\frac{3}{4} \times 1\frac{1}{4} \times \frac{1}{4}$	3	12	14	$3\frac{7}{8} \times 3\frac{1}{4} \times \frac{7}{16}$	9	0	10
$2\frac{3}{4} \times 2 \times \frac{5}{16}$	5	2	0	$4 \times 2\frac{1}{2} \times \frac{5}{16}$	7	0	0
$3 \times 2 \times \frac{3}{8}$	6	3	0	$4\frac{1}{2} \times 2 \times \frac{3}{8}$	11	1	14
$3 \times 2\frac{1}{2} \times \frac{3}{8}$	6	14	10	$5\frac{3}{4} \times 2\frac{3}{4} \times \frac{1}{2}$	15	14	10
$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	6	14	12	$6 \times 3 \times \frac{7}{16}$	13	14	10
$3\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	8	0	8				

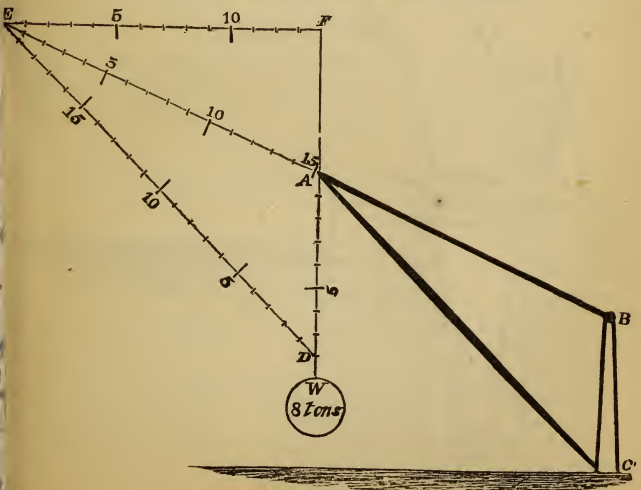
WEIGHT OF A SQUARE FOOT OF WROUGHT-IRON PLATE FROM $\frac{1}{32}$ TO 1 INCH THICK.

N.B.—A square foot $\frac{1}{8}$ of an inch thick weighs 5 lbs.

Thickness.	Weight.	Thickness.	Weight.
$\frac{1}{32}$	1·25	$\frac{1}{2}\ \frac{1}{32}$	21·25
$\frac{1}{16}$	2·5	$\frac{9}{16}$	22·5
$\frac{1}{16}\ \frac{1}{32}$	3·75	$\frac{9}{16}\ \frac{1}{32}$	23·75
$\frac{1}{8}$	5·	$\frac{5}{8}$	25·
$\frac{1}{8}\ \frac{1}{32}$	6·25	$\frac{5}{8}\ \frac{1}{32}$	26·25
$\frac{1}{8}\ \frac{1}{16}$	7·5	$\frac{11}{16}$	27·50
$\frac{3}{16}\ \frac{1}{32}$	8·75	$\frac{11}{16}\ \frac{1}{32}$	28·75
$\frac{1}{4}$	10·	$\frac{3}{4}$	30·
$\frac{1}{4}\ \frac{1}{32}$	11·25	$\frac{3}{4}\ \frac{1}{32}$	31·25
$\frac{5}{16}$	12·5	$\frac{13}{16}$	32·5
$\frac{5}{16}\ \frac{1}{32}$	13·75	$\frac{13}{16}\ \frac{1}{32}$	33·75
$\frac{3}{8}$	15·	$\frac{7}{8}$	35·
$\frac{3}{8}\ \frac{1}{32}$	16·25	$\frac{7}{8}\ \frac{1}{32}$	36·25
$\frac{7}{16}$	17·5	$\frac{15}{16}$	37·5
$\frac{7}{16}\ \frac{1}{32}$	18·75	$\frac{15}{16}\ \frac{1}{32}$	38·75
$\frac{1}{2}$	20·	1	40·

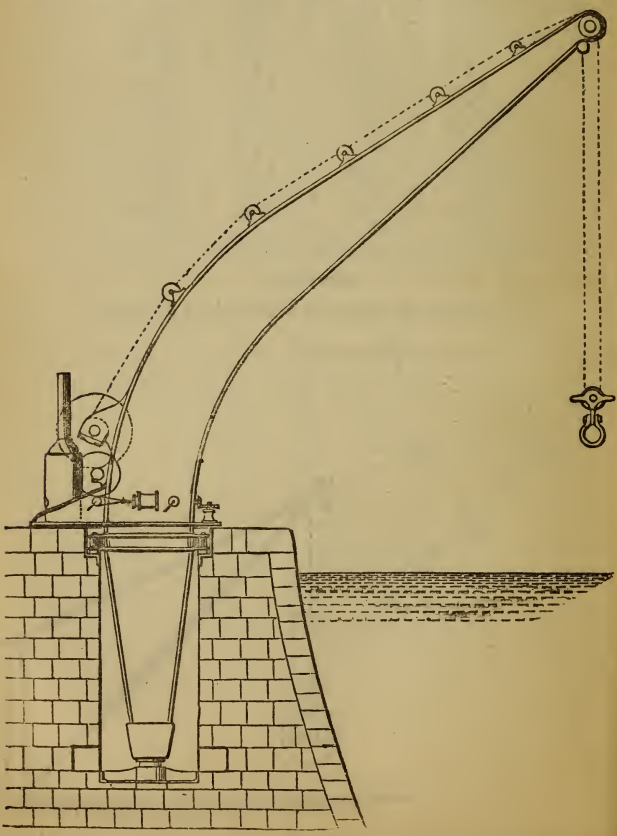
CRANES.

To compute the strains on a Crane by a Diagram.



From the centre of jib, A, on the vertical line A D, divide into as many parts as W has tons; draw D E parallel to the jib A C, until it cuts the line A B (on tension bar) produced to E; draw the horizontal line E F, and produce the vertical line A D to F. The thrust on the jib equals the line E D, 20 tons, as per diagram, tension on A B = 15 tons on the line A E. The crane-post, B C, may be considered as a beam fixed at one end, and loaded at the other at B; the weight being 14 tons on the line E F.

Height of handles above ground...	3 ft.	Each man exerts a pressure of...	28 lbs.
Radius of handle	16 in.	Angle of jib equals.....	45 deg.



Wrought-iron Steam Crane of 40 tons, for masting purposes, &c.

Wrought-iron Steam Crane of 40 Tons.

	Diameter at Pitch-line. ft.	in.	Breadth. in.	Pitch. in.	Diameter of Shaft. in.
Large spur-wheel	8	$2\frac{3}{8}$	8	3	$7\frac{1}{4}$
Pinion for ditto	1	$0\frac{1}{2}$	8	3	$3\frac{3}{4}$
Second spur-wheel	4	$2\frac{7}{8}$	$5\frac{1}{2}$	$2\frac{1}{4}$	$3\frac{3}{4}$
Pinion for ditto	0	10	$5\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{7}{4}$

Section of Jib, &c.

Top Flange or tension. 8 tons per square inch.	Under side or compression. 5 tons per square inch.	
21·5 square inches.	33·0 square inches.	10 feet from top.
30·0 ,,	46·0 ,,	20 ,,
34·6 ,,	53·2 ,,	30 ,,
50·0 ,,	77·0 ,,	40 ,,

N.B.—To be tested to 80 tons.

Two Steam Engines, $6\frac{1}{2}$ inches Diameter of Cylinders, Stroke 9 inches, with 40 lb. Steam.

Estimated Weight.

Wrought iron	42·0 tons.
Angle iron	11·7 ,,
Cast iron	24·0 ,,
	77·7 ,,

This is without engine and machinery.

Shop Travelling Cranes.

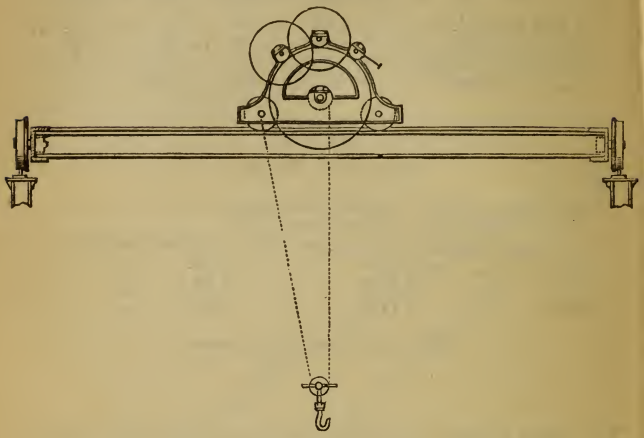
Taken from practice.

$$\frac{\text{Handle.}\quad 113 \times \overbrace{51 \times 97}^{\text{Teeth in wheels.}}}{\underbrace{11 \times 11}_{\text{Teeth in pinions.}} \times \underbrace{43{\cdot}9}_{\text{Barrel.}}} = \text{Power.}$$

$$\frac{\text{Handle.}\quad 113 \times \overbrace{50 \times 75}^{\text{Teeth in wheels.}}}{\underbrace{9 \times 12}_{\text{Teeth in pinions.}} \times \underbrace{39{\cdot}2}_{\text{Barrel.}}} = \text{Power.}$$

FIFTEEN-TON TRAVELLING CRANES

At the Royal Arsenal Gun Factory, Woolwich.



All the wheels 2-in. pitch.

Handle. Teeth in wheels.

$$\frac{106{\cdot}8 \times 62 \times 62 \times 100}{14 \times 14 \times 14 \times 36} = 415 \times 40 \text{ lbs. for 2 men} \times 2 \text{ for moving-block.}$$

Teeth in pinion. Barrel.

Equals 15 tons nearly.

	Tons.	Cwts.
Weight of 15-ton travelling crane with carriage complete	8	6
„ 25 „ „ „ „	13	5

RELATIVE STRENGTH OF GIRDERS, OR BEAMS.

Supported at one end and loaded at the other = 1
„ „ load distributed = 2

Supported at both ends and loaded at centre = 4
„ „ load distributed = 8

Or, otherwise, a beam will bear double when the load is distributed.

Firmly fixed at both ends = 12.

Or, conversely,

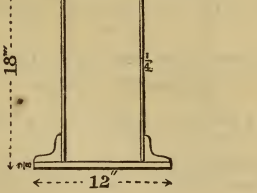
	Cwts.	
Say	8 = 20	supported at both ends.
„	4 = 10	
„	2 = 5	supported at one end.
„	1 = 2·5	

WROUGHT-IRON BEAMS.

The breaking weight in tons, at centre, is equal to the area of bottom flange, multiplied by the depth of beam at centre, multiplied by constant, dividing the result by the distance between supports (all taken in inches):—

Constant for plate beam is	.....	75
„ box „	.....	80
„ rolled „	.....	80

Those constants are for beams supported at both ends. Proportion of bottom to top flange is as 5 to 8.



Two girders for 15-ton travelling carriage, between wheels 28 ft., girders 18 in. deep; area of bottom flange, with angle iron, 6·37 square inches.

$\frac{6{\cdot}37 \times 18 \times 80}{336} = 27{\cdot}2 \times 2 = 54{\cdot}4$ tons breaking weight, or 3·6 times.

DIMENSIONS AND COST OF SOME WROUGHT-IRON, ETC., RAILWAY BRIDGES IN SCOTLAND.

VIADUCT OVER THE RIVER TAY AT DALGUISE.

Abutments and Pier of Stone.

2 spans of wrought iron, 210 ft. and 141 ft. openings; extreme length 515 ft.; height above the bed of the river 67 ft.

Cost, £20,395; cost per lineal foot, £39 12s.

VIADUCT OVER THE RIVER TUMMEL AT BALLINLING.

Piers of Cast-iron Cylinders.

2 spans of 122 ft. each, and 2 of 35 ft. each, openings; extreme length 350 ft.; height above the bed of the river 36 ft.

Cost, £11,156; cost per lineal foot, £31 17s. 6d.

VIADUCT OVER THE RIVER TAY AT LOGIERAIT.

Piers of Cast-iron Cylinders.

2 spans of 137 ft. each, and 2 of 41½ ft. openings; extreme length 419½ ft.; height above the bed of the river 49 ft.

Cost, £13,772; cost per lineal foot, £32 16s. 7d.

VIADUCT OVER THE RIVER TILT AT BLAIR ATHOL.

Abutments of Stone.

1 span 150 ft. long; extreme length 256 ft.; height above the bed of the river 40 ft.

Cost, £5,720; cost per lineal foot, £22 7s.

VIADUCT OVER THE RIVER DULNAIN.

Abutments of Stone.

1 span 80 ft. long; extreme length 148 ft.; height above the river 27 ft.

Masonry, £2,238; iron-work, £1,060.

Total cost, £3,298; cost per foot, £22 5s. 6d.

VIADUCT OVER THE SPEY, NEAR KEITH.

1 span of wrought iron 230 ft. long, and 6 side arches, of stone and brick, each 30 ft. span; height above the bed of the river 74 ft.; extreme length 660 ft.

Cost, £34,482; cost per lineal foot, £52 5s.

VIADUCT OVER THE RIVER FINDHORN, NEAR FORRES.

Stone Abutments and Pier.

3 spans of 150 ft. each, openings; extreme length 608½ ft.; height above the bed of the river 74 ft.

Masonry, £11,170; iron-work, £10,260.

Total cost, £21,430; cost per lineal foot, £35 4s. 4d.

SWING BRIDGE OVER THE CALEDONIAN CANAL.

Stone Pier.

2 wrought-iron girders, each 126 ft. long, set on a turn-table.

Cost, £4,718.

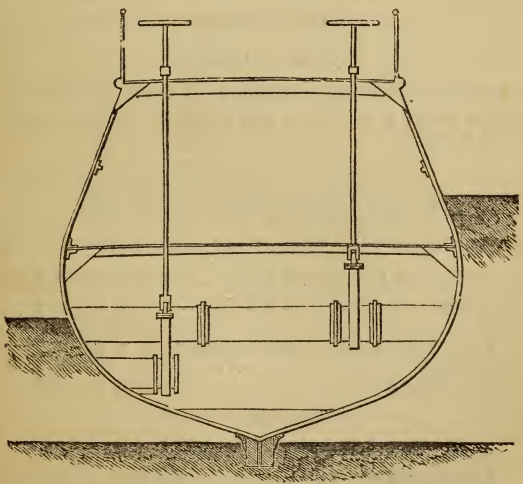
The cost of the iron-work for these bridges averaged £20 per ton.

CAISSON FOR DOCKS.

Water-lines a true ellipse.

	Ft.	In.
Length at top	128	0
„ bottom	122	0
Depth	15	5
Breadth	18	0

Wood-bearing surface, 1 ft. square, with angle iron 3 in. × 3 in. × ⅜ in.



Caisson for Dock.

SCANTLING.

Frames	$3'' \times 3'' \times \frac{3}{8}''$	
Beams	$4'' \times 3'' \times \frac{1}{2}''$	
Plating next keel..	$\frac{1}{2}''$	
Plating to turn of bilge	$\frac{7}{16}''$	
All other plates ..	$\frac{3}{8}''$	
Floors.....	$12'' \times \frac{3}{8}''$	on every alternate frame.
Keel	$12'' \times 1''$	likewise stem and stern-post.
Stringers	$3'' \times 3'' \times \frac{3}{8}''$	of angle iron, between top and lower deck.
Stringer	$12'' \times \frac{3}{8}''$	angle iron, $3'' \times 3'' \times \frac{3}{8}''$ on top.
,, ...	$12'' \times \frac{3}{8}''$	at diagonal trussing; diagonals, 6 in. $\times \frac{3}{8}$ in.

Three sluices through caisson, 18 in. diameter, with pipes of wrought iron $\frac{3}{8}$ in. thick; two 18 sluices for letting water into caisson; two double-acting pumps, 10 in. $\times$ 9 in. stroke. Deep caissons are ballasted with bricks set in cement.

LANDING STAGES ON THE THAMES.

PAUL'S WHARF.

Boat or Dumby.

Length, 27 ft. 6 in.; breadth, 9 ft.; depth, 4 ft. 10 in.

Bottom plates, $\frac{1}{4}$ in. thick; side plates, $\frac{5}{16}$ in. thick; all other plates, $\frac{3}{8}$ in. thick.

BOW LATTICE GIRDER BRIDGE,

FOR RAISING AND LOWERING AS THE TIDE FLOWS AND EBBS.

Length, 70 ft.; breadth, 6 ft. 6 in.; depth at centre, 4 ft.

Bottom angle iron, back to back ..	$3'' \times 2'' \times \frac{1}{4}''$
Top ,, ,, ...	$4'' \times 2\frac{1}{2}'' \times \frac{5}{16}''$
Uprights, 2 ft. 10 in. centre to centre	$2'' \times 2'' \times \frac{5}{16}''$
Diagonals	$2'' \times \frac{5}{16}''$
Cross floor pieces	$3'' \times 2'' \times \frac{5}{16}''$

Weight, 5 tons 12 cwt.

Flooring of $1\frac{1}{4}$-inch deck deal, 455 square feet.

Furring-out pieces (oak)	308 ft. $\times 2'' \times 2''$
Tread pieces (English oak)	227 ft. $\times 2'' \times 1''$

FIXED PARALLEL LATTICE BRIDGE ON PILES,

SUPPORTED IN THE MIDDLE.

Length, 136 ft.; breadth between uprights, 8 ft. 6 in.; depth, 4 ft.

Bottom angle iron, back to back ..	$2\frac{1}{2}''$	×	$2\frac{1}{2}''$	×	$\frac{3}{8}''$
Plate between	$8''$	×	$\frac{1}{4}''$		
Top angle iron, back to back	$4''$	×	$3''$	×	$\frac{3}{8}''$
Plate between	$8''$	×	$\frac{1}{4}''$		
Middle diagonals	$3''$	×	$\frac{3}{8}''$		
Diagonal truss	$3''$	×	$\frac{3}{8}''$		
Centre floor plate	$3''$	×	$\frac{3}{8}''$		
Diagonals, do.	$3''$	×	$\frac{3}{8}''$	×	2 ft. 3 in. between.

Weight, 12 tons 10 cwt.

Buckled floor plates, 1,150 sq. ft.; Portland cement, 884 sq. ft., 2 in. thick; asphalt, 884 sq. ft., $\frac{3}{4}$ in. thick.

KENT VIADUCT.

On cast-iron piles; light lattice-work; double line. Fifty bays 30 feet long, and one bay for open bridge 36 feet long in the clear. Height from top of rails to low-water mark, 23 feet. Length over all, 1,566 feet; 406 tons of wrought iron; 368 tons of cast iron. Cost, £20,813; cost per lineal yard, £39 17s. 5d.

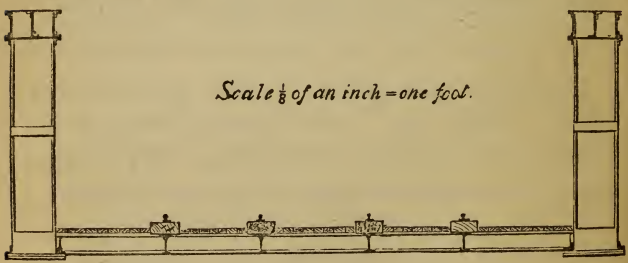
VIADUCT OVER THE THAMES AT STAINES.

Continuous plain girder; on piles and stone abutments; double line. Three openings, 88 feet 6 in.; and two side openings, 85 feet 3 in. The bridge is composed of three wrought-iron girders, &c., having a total length of 279 feet 8 in.; depth of girders, 7 feet 6 in.; supported with six cylinders, 6 feet diameter, 1 in. thick at top, and $1\frac{1}{4}$ in. thick at bottom. Weight of wrought-iron work, 193 tons. Cost, £10,000. Total weight, with rails, ballast, &c., 360 tons.

VIADUCT OVER THE TRENT.

Double line; stone piers and abutments; two spans of wrought iron; 154 feet long; breadth in the clear, 26 feet; depth of girder, 12 feet. Section according to woodcut and dimensions.

The cellular compartment at top is 3 feet $0\frac{3}{4}$ in. wide, and 1 foot 3 in. deep, with a central plate. The body of the box girder is 2 feet 6 in. wide, and the bottom flange of girder 3 feet in width; transverse iron box beams, 1 foot 3 in. deep, with top and bottom flanges 10 inches wide. These transverse beams are placed 4 feet apart from centre to centre, and rest on the angle iron, and are strongly riveted to the main girders. This bridge is simplicity itself, being strong and durable. Many bridges of this class span the thoroughfares of the metropolis; some



Box Girder Bridge.

are highly objectionable, having the transverse girders merely riveted to the under side of the main beams, and afterwards clumsily patched, to give

them the appearance of great strength. Such a practice should always be avoided.

The roadway is laid on timber, 1 foot × 7 inches, and the spaces between filled in with 3-inch planking.

Supposing this bridge to be loaded to $1\frac{1}{4}$ tons per foot run = 385 tons for both lines—and the combined areas of bottom flanges to be 100 square inches (and the constant 160)—

$$\frac{100 \times 144 \times 160}{1{,}848} = 1{,}246 \text{ tons},$$

or about $3\frac{1}{4}$ times the load on bridge. Of course this does not allow for the weight of the structure.

RIVETS FOR BRIDGES.

The rivets vary from $\frac{3}{4}$ inch to 1 inch. Pitch of rivets at top 3 inches, and at bottom 4 inches. All the plating should break band, and be in as long lengths as convenient.

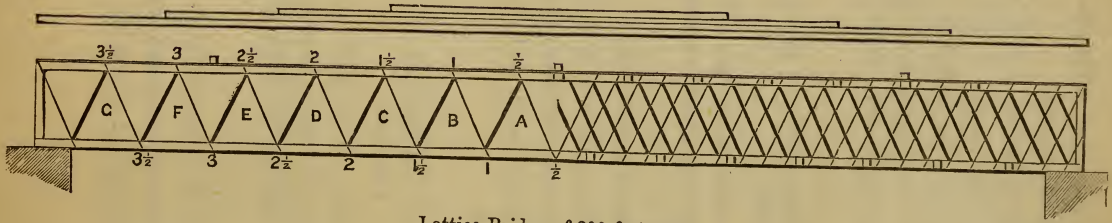
PROPORTION OF DEPTH TO LENGTH OF GIRDERS FOR BRIDGES.

The depth of girders for bridges varies from one-tenth to one-fifteenth of the span; however, in practice one-twelfth, or an inch to the foot, gives excellent results.

LATTICE GIRDER BRIDGES.

To find the strain on the top and bottom flanges, multiply the total weight of the bridge, adding the

Top Plating.

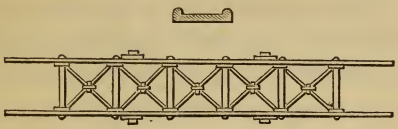


Lattice Bridge of 200 feet span.

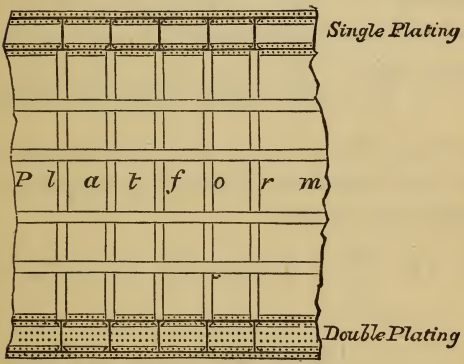
The fine lines are subjected to tensional strain, and thick lines to compression in the ties and struts.

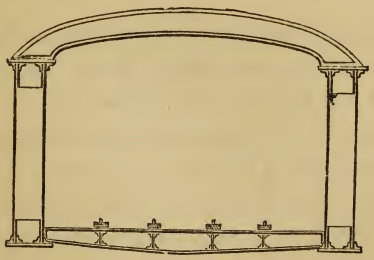
Bottom Plating.

rolling load as 1 ton to every foot forward, into the length of span in inches, divided by the sum of



Compression Bar.





the depth (into the constant 8), also in inches, and the quotient gives the strain on the top and bottom

flanges; then dividing by 5 for tension, and 4 for compression, gives the number of square inches of section. Thus, supposing the span to be 200 feet long, 16·66 feet deep, and the bridge loaded to, say 700 tons, distributed on the two lines of rails (this includes the weight of structure)—

$$\frac{700 \times 2400}{199{\cdot}9 \times 8} = \frac{1050}{5} = \frac{210}{2} = 105 \text{ square inches}$$

for each lattice at bottom, and

$$\frac{1050}{4} = \frac{262}{2} = 131 \text{ square inches for top flange.}$$

Now, taking the width of the bottom flange at 30 inches, and making an allowance of 6 square inches for angle iron, we have

$$105 - 6 \quad \begin{matrix} 99 \\ 30 \end{matrix} = 3{\cdot}3 \text{ in. thick for bottom flange,}$$

and

$$131 - 6 = \frac{125}{30} = 4{\cdot}1 \text{ in. thick for top flange.}$$

The plating is arranged as per woodcut, three thicknesses at middle for bottom flange, and four thicknesses for top flange. The strain on each triangle for the ties and struts is represented by the figures, and the load on each being 50 tons, as there are 43 points of attachment, there will be 8·14 tons on each for single girder. Now, as a rule, each tension bar for such structures is $4\frac{1}{2}$ in. $\times$ $\frac{1}{2}$ in. thick at the middle of bridge = 2·25 square inches, or 1 inch to the ton

nearly at middle in the solid, and at the ends on piers, 2·25 × 3·5 for bridge of 200 feet span = 7·875 square inches, say $10\frac{1}{2} \times \frac{3}{4}$ of an inch, this being taken from some recent examples. The compression bars are as 3 to 5, or equal to 3·75 square inches for each bar at middle, and are arranged as per wood-cut. The tension bars, at ends for eight bars have eight rivets securing them to girders, all the rest having six rivets. The riveting across the bottom and top has four rivets for single plating, and six rivets for double plating and upwards.

LOCOMOTIVE ENGINES.

INTRODUCTION.

The express locomotive engine may be aptly compared to an English race-horse, graceful in form and fleet as the wind. The rapid progress of the machine has been remarkable. When the great father of locomotives presented the clever crudities of the "Rocket" before the public, clearly proving that the infant machine could travel at a pace of 30 miles an hour, it became quite evident that on arriving at mature growth the speed could be increased; and when the bite of the wheels on the rails was found to answer, so that gradients of 1 in 42 could be ascended without the aid of racks, spur-wheels, &c., a new era in civilised life was opened up. But few at first directed their minds to the development of the machine until Stephenson had put it into shape. Indeed, the task was no easy one, if we consider such a complicated piece of mechanism crushed into so small a space. The breathing power, or steam pressure, had to be greater than ever before attempted, and the "pulsations" to be increased threefold, the great secret of success being a suppression of part

of the motive power by the introduction of the steam-blast. Whether this was the result of deep study or an accidental discovery matters little; suffice it to say that the locomotive could not have attained such rapid strides without the steam-blast. But for this we should probably still be travelling in the old stage-coach, or at about the same speed.

George Stephenson had many prejudices and obstacles to encounter before he proved that, with the aid of the multitubular boiler and steam-blast, the locomotive was the quickest and most powerful mode of transit. Looking back to the period when the machine was of such imperfect design, compared with the locomotives of the present day, no one can deny that the driver of the "Rocket" was a daring man to drive the engine at 30 miles an hour—three times the speed of the old stage-coach, and twice as fast as the celebrated Manchester "Telegraph," or no less celebrated Halifax mail. Indeed, considering the imperfect permanent way at that date, it was a marvel that the locomotive kept on the metals at all, for it was not till 85 lbs. per yard rails were adopted that we could consider the locomotive railway system at all a safe one. All honour then to the colliery engineer, who, with such difficulties to encounter, finally succeeded in placing the locomotive on the rails as a pattern to all nations. That American and continental makers can come up to us in producing as good workmanship there can be no doubt, but look at their

engines and look at ours. The cabs and the cow-catchers, cone-funnels, large forward-lamps, and great bells are very essential for the wilds of America; and the continental mountain locomotive, with its small coupled wheels, bogie-frames, chain pulleys, and mid-rails, though very clever, is nevertheless clumsy, compared with the "Lady of the Lake" of 1862, or the British engine of 1867 at the Paris Exhibition. There the engines of all nations were assembled in public competition, and who will deny that for clean finish and general contours Great Britain won the day? The cause of our great success is simply owing to the high state of perfection we have attained in design and proportion. Many minds have been engaged in perfecting the construction. However, the chief features—such as the multi-tubular boiler, the steam-blast, and the link-motion —were first introduced by the Stephensons. Many schemes for valve-motion were tried, and, for a time, worked satisfactorily; but the single link and double eccentrics certainly constitute the best and only good motion now in use. Indeed, for marine and colliery engines, the link-motion is extensively used. I am not aware if George Stephenson ever applied it to winding engines, or to marine purposes; but when it could be successfully applied to the locomotive, it required little foresight in its application elsewhere, and for winding engines it is the safest that can be adopted.

Although four-wheeled engines were much used at one time, they have been entirely discarded for passenger engines, owing to the violent oscillating motion at high speed; but they are still used for mineral traffic. As the demand for heavy engines increased, six-wheeled engines were adopted, and now the six-wheeled locomotive is the recognised British type, although in some instances eight wheels are adopted. When we consider the wear and tear a locomotive is subjected to, the small area it covers, the perfect control of its tender, and even of itself, the means it possesses of reversing, stopping, or going at high speed within a hundred yards or so, it is certainly, as a whole, the greatest triumph in steam machinery; and when we know that in days gone past it was constructed by hand labour alone, it is a marvel of skill that British workmen can proudly look back to.

It soon became evident that, to manufacture cheaply, special machines were requisite, and the variety of specialities now in use for constructing general machinery were, I may say, first adopted by locomotive manufacturers. The next step in improvement was placing the cylinder under the boiler, and inside of the smoke-box; but further improvements were developed by placing the boiler independent of the machinery. The old mode of attaching the horn-plate to the fire-box and smoke-box was both a laborious and unsatisfactory arrangement. In some

cases the end of the horn-plate at the fire-box was fitted into a socket, so that it slid as the boiler expanded or contracted, but in most instances the fire-box and smoke-box were rigidly held by the horn-plate, the expansion of the boiler causing a severe strain. Now the inside frame, or horn-plate, is carried the entire length between buffer, or front beam, and the end one, and the cylinders are fitted thereto, independently of the boiler, the boiler merely resting on the top of framing. By this means it expands and contracts without materially straining the machinery, and the framing of itself takes the hauling power. The economy of the locomotive depends on a variety of circumstances. Firstly, the design must be good, and the workmanship the best that can be produced; secondly, the permanent way must be in first-rate condition; and thirdly, both drivers and firemen must understand their business. To attain a proper proportion of fire-grate; to extract the useful caloric, the top and sides of fire-box being the best steam-producer; and to concentrate the heated gases by the system of small tubes, honeycombing, as it were, the cubic water-space by hundreds of square feet of heating surface, and after the flame has done its best duty in the fire-box, drawing through the heated gases with the powerful steam-blast, until the "refrigerator," acting on the tube surface, reduces the fiery element, or extracts its useful properties, depends greatly on skilled men

as drivers and firemen. The former must feed up in a careful manner, taking advantage of going down inclines and entering stations as the best time to turn on the water from tender. He must likewise bottle up the steam, as it were, so as to have a good command in ascending inclines; to do so properly he must be fully acquainted with the line. On easy railways his duty is comparatively light compared with lines having frequent and steep gradients to ascend. He must likewise have other qualifications. A good driver can at once detect the slightest defect in the machinery, going at forty miles an hour; and should he consider it sufficient cause for alarm, will stop the train, or make good the defect at the next station. Such are the qualifications of a good and economical driver, but he has likewise other duties to perform, as he must note any irregularities on the line, for the safety of the passengers is in his hands.

Coke premiums were at one time the means of inducing a more careful method of firing. Striving to make the coke bill as small as possible, they managed, on occasions, to show a wonderful reduction. This was a marvel at the commencement of the system; but it soon leaked out that it could be traced to other causes, more especially when trains passed through a mineral district. Still, in ordinary circumstances, some showed a reduction which must have arisen mainly by a more careful study of the art of firing up. This duty is essentially that of

the fireman, as the driver should never look into the fire-box, for at any second of time he may require the full use of his eyesight, so as to recognise any obstruction on the line. An amateur gazing into the furnace, and then looking ahead, could not distinguish objects for a second or two; but use is second nature, and a skilled fireman can at once detect where to throw on the coals, so as to keep the grate always covered. Preventing a rush of cold air, and keeping the furnace door open as little as possible, constitute the art of firing. Coke bills are a mere secondary consideration.

Steel tires and rails must form a great source of saving in the future, and although a certain class of engines on one railway may show more economy than the same type of engine on another, that must simply be attributed to the duty to be performed being easier in the one case than the other. Let us take the network of railways in the metropolis. Look at the complication at the Battersea Station; see one train coming thundering down an incline without the use of the steam, and another alongside using all its tractive power to ascend. Compare the economy of these lines with lines almost level throughout, and the latter will show a less figure for repairs. The greatest source of economy must be by a reduction of the weight of engine, or by using the best type. It appears to me that the medium wheels are the most economical working engines. Engines

with 7 feet 6 inch drivers have the same tractive power as those with 5 feet 6 inch wheels coupled. Indeed, it can be made more if required for the small wheel, yet the weight of the express engine may be 27 tons, and the coupled-wheel engine 18 tons on the average, while the adhesive power of the light engine is more than the express heavy one. This to some may appear a paradox, but it is a fact. Many thought at one time that coupled wheels could not be driven at high speed, but that idea has long ago been exploded, for coupled-wheel engines are generally recognised to be the best under all circumstances, as, although the speed of piston may be greater, the weight is much less, and consequently the permanent way will be easier kept in repair.

The locomotive at the present day seems to have arrived almost at the acme of perfection; however, we may still look for further improvements. A good system of using the hot-water tender and hot-water tank engine is a step in the right direction. The great field for further improvement lies in the construction of the railway itself. A line may be so constructed that it can never become a paying speculation. The history of one railway is totally different from that of another; the difficulties Stephenson had to encounter at Chat Moss being quite distinct from those of the Chester and Holyhead line, with that monument of skill, the tubular bridge, towering 100 feet above the Straits. Take, too, the Under-

ground and Metropolitan grand circuits, the Mont Cenis ascending line, and the tunnel through the Alps.

The manufacture of the locomotive presents no striking difficulties, the pattern-making consisting of cylinders, axle-boxes, small pattern brasses, &c.; and as many castings are required, the small patterns are made in hard wood. To manufacture cheaply, a low rate of wages must be adopted, or the special machines should be attended to by apprentices, for when the uses are properly machined, little fitting or finishing is required. Indeed, we have seen large links for the valve-motion of heavy marine engines finished entirely in the machine. However, for getting up cylinders, connecting-rods, turning wheels and axles, for boiler-making and forging, more than ordinary skilled labour is required, forging cranked axles being the most difficult to execute. Indeed, these are generally ordered from some firm devoted to that class of work. In some instances the cranked axle is formed from a straight bar of iron, the cranks bent into shape by hydraulic or other power. Forging wheels in the factory requires good smith's work. The spokes are formed with a wedge-shaped piece at the nave, and T shape for the inner tire or ring, the ends of the T being bevelled, so that when the spokes are put together, a series of wedge-spaces is left to be welded up. After the spokes are finished they are taken to the grinder to

be ground by a revolving stone, so as to make them quite smooth. The spokes are then put together, and are held in position with a strap and screw, when the nave is placed in the fire, two smiths being required, one attending to the nave itself, while the other heats a round thick washer, to be welded over the nave when the wheel has attained a welding heat. The smith generally gives the screw in strap an extra turn, forcing the wedges at nave closer together. When both are ready they are taken out, the washer placed over, and a few strokes of a suitable steam hammer unite the mass, which is then dressed off with hand labour.

After the nave is completed the strap is removed, and a straight bar attached, with means of turning the wheel over, so that the wedge-pieces in the tire can be welded up bit by bit. The tires are generally ordered from the mill in hoops entire; as such they require only to be turned in the factory, the outside tire having a convex surface, and the inner a concave one. After the inner tire and outer one are turned they are taken back to the smith, who heats the outer tire in a furnace for that purpose, and the spoke-wheel being placed in a circular trough, the tire is taken out of the furnace, placed over the spokes, and water turned on; the outer tire is thus shrunk on, just in the same way as a country smith shrinks on the ring of an ordinary cart-wheel. And as a piece of handicraft, a locomotive wheel, well

executed, is a part of the work of which both master and man may be proud. The other uses require ordinary skill in smith's work. Small steam hammers are so placed that two smiths can make use of them for doing the rough work. Hammermen, however, cannot be dispensed with for dressing up the forgings.

The boiler-maker, with the use of multiple punching and steam-riveting machines, quickly forms the body of boiler; but the fire-box plates, &c., must be carefully flanged and riveted up by hand, the tube centres accurately set out and drilled, and the inside or copper fire-box well flanged at bottom, and stay-holes bored through outer and inner fire-boxes, for the reception of screwed stays, 4 inches by 4½ apart. A locomotive boiler and tender are a nice piece of work; the well-rounded rivet-heads being neatly executed, more especially for the tender, as irregular work there would offend the eye. However, I think all tenders for hot water should be clothed the same as the boiler, with felt, wood, &c. The boiler, after it is finished, is tested with water pressure to about double or one and a half times the working steam-pressure. The boiler shop is a noisy place. See a first-class workman hammering at a piece of crumpled-up boiler-plate, somewhat the shape of a wash-hand basin, and you naturally ask yourself, Will he ever beat it into a smooth surface? This is what he has to do, and to form a finely-curved chimney-top out

of a round plate, with a small hole in the centre to prevent the plate splitting.

In the palmy days of locomotive manufacture, the erecting-shop presented a stirring scene, the arrangement of this department being totally different from other erecting-shops devoted to mechanical industry. The locomotive is erected over a pit the breadth of the shop; as each engine requires a separate pit, so as many pits as the shop will hold, as many locomotives can be turned out. All the pits are furnished with rails, and the shop should be so placed that the engine, when completed, can steam out of the factory on to the line of railway, and thus arrive at its destination in perfect condition and ready for use, without the necessity of being pulled to pieces and packed up for transportation. We have known some shops to bring out one locomotive per week; not that the machine could be made in so short a time, but when a number are gradually progressing, such a feat has been readily accomplished. And we have known all the erecting done by young men still serving their apprenticeships.

The "locomotive start" gives a kind of gala to the factory, and though certainly a "locomotive start" in the workshop falls very short of the imposing appearance of the launch of a steam ship, to many it is far from devoid of interest. In railway workshops the engine is put to a severe test. A skilled driver will curb the machine, as it were, to

try its metal; and then, when he sees a clear line before him, will dash off at fifty miles an hour, and take a good run at that speed.

The following estimate of the cost of a locomotive may be taken as a guide to the average cost of all. Part of the machine must still probably be done by hand labour; whether machinery can execute the whole of it, depends on the form it is put into. The more simple the design, the lower will be the first cost. Consequently, as manufacturers will be able to compete with those who are contented with moderate profits, and have a command of cheap skilled labour, I propose at this stage to give the time and prices of piece-work as let out to the men by some Scotch and other firms.

PATTERN MAKING.

	Days.
Two cylinders, right and left, complete	36
Axle-boxes, all of the same size	9
Brasses for connecting-rods	1½
Pumps with valves complete	9
Safety-valves	2½
Eccentric and rings	9
Cocks	5½
Piston	8
Slide-valve and V guide	4½

The above form the principal details.

BOILER MAKING.

Taken at 15s. per cwt., without tubing (same at Newcastle, 17s. per cwt.)

Tank for a large size tender, time, about three weeks, taken at £7 17s.

FORGING WHEELS.

Five-feet wheels, with 14 arms, taken at £3 1s. 6d. It is thought that all 5-feet wheel spokes can be forged, for each spoke, at 4s. 6d.

Welding wheel centre, 5 feet diameter, and inner tires, each at £2 2s. 6d.

Ditto for 3 feet 6 inch wheels, £1 16s.

Two sets of tender smith work, 9s. 6d. per cwt.

Outside connecting-rods (ordered out), with hole for brasses cut out, at per cwt., delivered from Carlisle, 18s. 6d.

BOLTS AND NUTS.

Five sets of bolts for trucks, 98 cupped heads, 24 square ditto in each set (610 bolts in all), take two smiths and two hammermen $7\frac{1}{2}$ days to forge, this being at the rate of about 40 per day—bolts $\frac{3}{4}$-inch diameter.

LOCOMOTIVE FORGINGS.

Small Work.

Taken at 14s. 10d. per cwt.

Mineral Wagon, &c.

Mineral-wagon and luggage-van forging (ordered out) average from $3\frac{1}{4}$d. to 4d. per lb.

Wheels at a railway factory taken at 23s. per cwt., this includes striker and repairing tools, and shrinking on of tires.

Engine wheels from Newcastle delivered there, 5 feet diameter, 14 arms, at £1 13s. per cwt., not including tires.

Truck Wheels.

Offer as sent from Newcastle, delivered there, 3-feet wheel, 8 arms all; the arms double, and welded at inner tire, 34s. per cwt.; when the inner tire is made equal with the arms, 31s. per cwt.

Wheels without tires, 447 lbs., at £1 11s. per cwt.

Tires	672
Axles	296
Total weight	1,415

Contract.

All the wrought-iron work for landing slips on the Tay ferries, 20s. per cwt.

Castings turned, &c., 12s. 6d. per cwt.

Brass work, 1s. 6d. per lb.

Total weight, about 110 tons.

Turning, &c.

	Days.
Cranked axle, small size, takes about	10
Ditto, large size	13½
Slotting out blocks	5½
Chipping and boring out	9
Leading and trailing axles, with outside crank, each	2
Tender axles, 6 off	6½
Engine axle-boxes, boring out 6 off (and facing)	5½
Planing ditto	4½
Boring and turning 6 tender axle-boxes	4½
Planing ditto	3
Pistons, 16 inches diameter, 2 off	6
Cylinders, boring out, 2 off	8
Planing all the faces	14
Axle-box guides, 12 off (planing)	2½
Wheels, 5 feet diameter, out and in tires, eye, &c. (each)	6
Motion-bar, with long turned end, with nuts at each end, 8 off	10
Planing ditto (each)	3½
Weigh-bars (cranked) 3 off	5½
Slotting outside connecting-rods (each)	1½
Slotting reversing links, 2 off	3
Planing outside rods (each)	1

Fitting.

	Days.
Cylinder, 16 inches diameter, complete (2 men)	24
Engine axle-boxes, 6 off	6
Tender axle-boxes, 6 off	4½
Putting on a set of wheels with outside cranks, the keys being cut off, but not filed	22½

Finishing.	Days.	Rate of Wages per Week.
4 eccentric straps, rods, &c. (each)	8	18s.
2 inside connecting-rod (each)	6¼	,,
4 outside connecting-rods	18¼	,,
Fitting and finishing 2 sets of brake gear, 2 men, taken at £7		
Pump, 3 pairs, complete	13	12s.
1 set of reversing weigh-bar arms	6¼	,,
2 inside horn-bar, brass, complete	5½	,,
1 reversing-handle and rod	11¾	,,
2 pistons and 2 cross-heads	20	,,
2 sludge-cocks		7s. 6d.
2 ball-and-socket pipes (each) 12s.		
2 reversing-links, slides, and eccentric rod-ends, complete and cast hard	25½	12s.
2 waste-cocks (each) 2s. 6d.		
4 heating-cocks (each) 4s. 6d.		
Pump-valves (each) 9d.		

The preceding estimates show the time taken for the principal parts of the locomotive. I will now give—

A COMPLETE SPECIFICATION OF A MINERAL ENGINE AS ESTIMATED IN A RAILWAY SHOP.

	Per lb.	Material.			Fitting, forging, and turning.		Total.		
	d.	£	s.	d.	£	s.	£	s.	d.
Brass	9	35	14	9	30	0	65	14	9
Boiler-plates	2	54	14	2	60	0	114	14	2
Furnace-bars	2	8	11	6	5	0	13	11	6
Tubes	0	89	5	0	4	0	93	5	0
Axles	2	8	2	8	6	0	14	2	8
Framing	2	27	12	6	39	6	66	18	6
Draw-links	2	1	2	0	2	5	3	7	0
Spring mounting	2	4	12	8	9	17	14	9	8
Piston and connecting rods	2	10	5	4	37	0	47	5	4
Eccentric rods	2	8	9	2	42	12	51	1	2
Tires (wheels cast in)	$0\frac{1}{2}$	10	10	1	38	0	48	10	1
Stays	$1\frac{1}{2}$	2	5	$10\frac{1}{2}$	12	0	14	5	$10\frac{1}{2}$
Hand-rail	$1\frac{1}{2}$	1	3	$1\frac{1}{2}$	7	0	8	3	$1\frac{1}{2}$
Springs (steel)	0	5	6	8	2	0	7	6	8
Cast iron	1	41	12	3	39	0	80	12	3
Copper	9	12	1	6	14	0	26	1	6
		321	9	3	348	0			

	£	s.	d.
Material	321	9	3
Fitting, &c.	348	0	0
Fitting up a floor	200	0	0
	869	9	3

Add 25 per cent.—say £1,086.

The weight of the engine without water, 14 tons; the cylinders were 14 inches in diameter; stroke 24 inches, lying at an angle of 16°; wheels cast iron, 4 feet 6 inches diameter, and 2 off; the engine was fitted with a saddle-tank over the boiler.

For a similar class of engine, having 15-inch cylinder; stroke 22 inches; wheels 4 feet. Offers by three firms, £1,260, £1,280, and £1,200, the latter accepted. The fire-box was simply a round barrel of wrought iron, a plan, however, which has not come into much use.

FORGINGS FOR A SIX-WHEELED LOCOMOTIVE ENGINE.

Uses marked thus * are ordered out.

	cwts.	qrs.	lbs.	Days.	Hrs.
2 slide-valve rods	0	3	8	2	0
2 V slides	0	2	0	2	5
2 inside connecting-rods and straps*	4	2	21	3	1½
Assisting at ditto	0	0	0	1	8½
6 short horn-stays	2	2	17	5	7
Assisting at ditto	0	0	0	0	2½
6 outside connecting-rods*	3	2	6	4	6
2 joints for ditto	0	2	5	1	2
4 eccentric rods	1	3	9	4	4
4 axle-box guides*	0	3	12	1	1½
Assisting at horn-stays	0	0	0	0	5
2 piston-rods	0	0	25	0	5
2 hoops for pistons	0	0	2½	0	1
4 siphon covers for connecting-rods	0	0	8½	0	2½
4 cutters and jibs for ditto	0	1	26½	1	3½
6 ¾-inch bolts (steel)	0	0	3	0	1½
2 cross-heads	1	0	5½	3	2½
2 safeguards	1	0	11½	5	0
Assisting at ditto	0	0	0	0	5
2 reversing-links (steeled)	0	3	8	4	0
4 links	0	1	7	1	5
8 steel pins	0	0	21½	0	7½
4 stud-plates	0	0	24	2	0
6 washers	0	0	3½	0	1½
8 1⅛-in. cutter-bolts	0	0	15		
8 ¾-in. stud-bolts	0	0	6½	1	0
16 1-in. bolts, 32 nuts	0	1	23		
8 steel cutters	0	0	1½		
8 outside cranks*	6	3	19	8	5½
Assisting at ditto	0	0	0	0	2
2 motion-bars	0	3	12	0	9
Bolts for cylinders	1	0	25½	5	7
1 regulator-handle	0	0	15	1	0
1 reversing-handle	0	1	10	1	7½
1 regulator-rod	0	2	5	1	3

	cwts.	qrs.	lbs.	Days.	Hrs.
1 reversing-rod	0	2	17	1	5
1 steel pin	0	0	4¼	0	1¼
2 angle pieces for steadiment	0	1	10½	0	8½
12 ¾-inch bolts	0	0	14	0	3½
2 steel springs	0	0	1	0	1
1 arm for regulator	0	0	15	0	2½
1 stud for ditto	0	0	5½	0	1½
2 pins and 2 nuts	0	0	18	0	5
1 motion-bar steadiment, angle iron for ditto	2	2	10	3	8½
3 ⅞-in. stud-bolts	0	0	1¾	0	0¾
6 steel keys for connecting-rods	0	1	2	0	9
2 ditto set bolts	0	0	4¾	0	2
6 syphon covers ditto	0	0	13⅓	0	2
8 ⅞-in. bolts for piston	0	0	9	0	2
4 ⅞-in. bolts ditto	0	0	2½	0	1
2 cutters	0	0	6½	0	1½
1 box, key, and handle	0	0	10	0	2½
2 steel springs	0	0	1¾	0	1½
4 centre pieces connecting-rods	2	2	18	1	2½
1 quadrant and 4 bolts	0	3	17	2	2⅓
4 screws and jam nuts spring gear	0	0	25	0	9
8 spring-pins and guides	0	0	27½	1	5
24 links for ditto	1	1	1	5	0
12 1¼-in. bolts for ditto	0	1	10	0	7½
12 1-in. bolts for ditto	0	1	9	0	6
2 spring-pins	0	0	7	0	1½
28 ⅞-in. bolts for frame	0	0	23¼	1	0
2 ¾-in. bolts ditto	0	0	4¾	0	1
2 spring-pin bearers	0	0	5½	0	2
1 weigh-bar	0	3	0		
1 ditto carriage	0	3	5	5	0
4 arms for ditto	0	2	12		
1 washer and tap-bolt	0	0	2		
1 motion-bar steadiment	2	0	0	3	5
2 horn-bars	11	1	19	4	7½
Assisting ditto	0	0	0	3	0
24 guides for spring harness	0	2	10	2	0
12 pins for ditto	0	1	22	0	5
24 ¾-in. bolts	0	0	21⅓	0	6
1 drag shackle	0	1	10	1	0
4 ¾-in. bolts	0	0	5½	0	1
1 pin for drag gear	0	0	21	0	4½
2 angle plates	0	0	24	0	8½
14 angle plates for framing	1	2	18	0	5
12 stays ditto	3	1	16	0	7
26 1-inch bolts	0	1	8	0	8
2 keys for cross-head	0	0	5	0	1
24 ⅞-in. bolts for brackets	0	0	24	0	8

	cwts.	qrs.	lbs.	Days.	Hrs.
24 $\frac{7}{8}$-in. bolts for brackets	0	1	$2\frac{1}{2}$	0	8
4 pins and 8 washers	0	0	$8\frac{1}{2}$	0	$1\frac{1}{4}$
1 set of safety-valve gear	0	2	10	2	3
14 $\frac{3}{4}$-in. bolts for cylinders	0	0	$8\frac{1}{4}$	0	$2\frac{1}{4}$
10 1-in. ditto	0	0	$22\frac{1}{4}$	0	4
16 1-in. tap-bolts ditto	0	0	24	0	5
2 plates	2	1	$15\frac{1}{2}$	0	$6\frac{1}{2}$
7 nut-keys	0	1	4	2	7
1 set of fire-irons	0	2	6	1	2
4 ash-pan hangers	0	1	$1\frac{3}{4}$	1	4
1 drag shackle	0	2	22	2	5
8 $\frac{7}{8}$-in. bolts for buffers	0	0	$17\frac{1}{2}$	0	$3\frac{1}{2}$
4 $\frac{7}{8}$-in. ditto safeguards	0	0	$14\frac{1}{2}$	0	$1\frac{1}{2}$
2 $\frac{3}{4}$-in. bolts	0	0	$1\frac{1}{2}$	0	$0\frac{1}{2}$
1 angle-iron stay	0	2	15	0	5
6 steel keys for cranks	0	0	8	0	$2\frac{1}{2}$
10 1-in. bolts for frames	0	0	$22\frac{3}{4}$	0	4
6 $\frac{5}{8}$-in. ditto	0	0	$2\frac{3}{4}$	0	$1\frac{1}{2}$
4 $\frac{3}{4}$-in. ditto	0	0	$2\frac{3}{4}$	0	1
2 plates for drag gear	0	3	26	0	4
8 $\frac{5}{8}$-in. stud-bolts	0	0	3	0	2
2 ditto ditto	0	0	3	0	2
16 $\frac{5}{8}$-in. ditto	0	0	6	0	4
36 $\frac{5}{8}$-in. tap-bolts	0	0	$10\frac{3}{4}$	1	0
17 $\frac{3}{4}$-in. stud-bolts	0	0	$14\frac{1}{2}$	0	$7\frac{1}{2}$
4 $\frac{5}{8}$-in. ditto	0	0	$1\frac{3}{4}$	0	1
2 hand-rails and knobs	0	0	13	0	2
1 steel ferrule	0	0	$1\frac{3}{4}$	0	1
2 keys for cylinders	0	0	$9\frac{3}{4}$	0	2
6 $\frac{1}{2}$-in. bolts for springs	0	0	$3\frac{1}{2}$	0	$1\frac{1}{2}$
2 pieces of angle iron	0	0	$6\frac{3}{4}$	0	$0\frac{1}{4}$
6 $\frac{5}{8}$-in. tap-bolts	0	0	$1\frac{3}{4}$	0	$1\frac{1}{4}$
48 $\frac{1}{2}$-in. ditto	0	0	$6\frac{1}{2}$	0	$0\frac{1}{2}$
36 $\frac{3}{4}$-in. ditto	0	0	$2\frac{3}{4}$	1	$0\frac{1}{2}$
12 $\frac{7}{8}$-in. bolts	0	0	14	0	5
6 $\frac{7}{8}$-in. ditto	0	0	7	0	$2\frac{1}{2}$
8 $\frac{5}{8}$-in. ditto	0	0	6	0	4
4 $\frac{5}{8}$-in. ditto	0	0	$4\frac{1}{2}$	0	$2\frac{1}{2}$
30 $\frac{7}{8}$-in. ditto	0	1	13	1	0
8 1-in. ditto	0	0	$12\frac{3}{4}$	0	3
6 $\frac{3}{4}$-in. ditto	0	0	$4\frac{1}{2}$	0	$2\frac{1}{2}$
10 $\frac{3}{4}$-in. ditto	0	0	$7\frac{1}{2}$	0	$4\frac{1}{2}$
1 steel pin	0	0	$2\frac{1}{2}$	0	$1\frac{1}{4}$
3 1-inch nuts	0	0	$1\frac{1}{2}$	0	$0\frac{1}{2}$
6 plates	0	0	21	0	$1\frac{1}{2}$
2 $\frac{7}{8}$-in. bolts	0	0	4	0	$1\frac{1}{2}$
6 plates drag gear	0	1	2	0	2
6 $\frac{3}{4}$-in. bolts for steam-pipes	0	0	$4\frac{3}{4}$	0	3
6 $\frac{3}{4}$-in. ditto	0	0	$4\frac{3}{4}$	0	3

	cwts.	qrs.	lbs.	Days.	Hrs.
2 ¾-in. bolts for steam-pipes	0	0	1	0	0¾
12 ¾-in. ditto	0	0	5½	0	3½
4 1-in. bolts driving motion	0	0	16½	0	3
8 1-in. tap-bolts ditto	0	0	11	0	3
1 angle-iron stay	0	2	10	0	5¾
1 handle for grease-cock	0	0	2	0	1
4 ¾-in. tap-bolts	0	0	2½	0	1
2 ¾-in. ditto gauge-cocks	0	0	1½	0	0½
2 1-in. bolts doors	0	0	1½	0	0¾
8 ⅝-in. bolts	0	0	2½	0	2½
2 pieces of angle iron	0	0	4½	0	0½
2 syphon studs	0	0	8¼	0	7½
34 ⅝-in. bolts	0	0	11	0	6½
24 ¾-in. studs, 48 nuts	0	0	24	0	6½
10 ¾-in. studs	0	0	6	0	3
4 ⅝-in. bolts	0	0	2½	0	1
2 1-in. tap-bolts	0	0	2	0	0½
2 hand-rail knobs	0	0	14	0	3
2 ⅝-in. bolts	0	0	1	0	0½
2 pieces of angle iron	0	0	8	0	0½
1 set of cleading hoop ends	0	0	17½	1	3
1 set of sludge-cock gear	0	0	21¼	1	0
4 eccentric-rod shut	0	0	0	1	2
Altering ditto	0	0	0	0	3
2 1⅛-in. bolts	0	0	7¼	0	1½
2 pipe stays	0	1	8	1	3
2 foot-steps	0	2	16	2	0
4 ½-in. bolts sludge-cocks	0	0	2	0	1
Shutting two inside connecting-rods	0	0	0	0	6¾
Ditto 4 outside ditto	0	0	0	1	8¾
Ditto steadiment	0	0	0	0	7½
Ditto ditto	0	0	0	0	4
Assisting outside rods	0	0	0	0	3
Ditto inside ditto	0	0	0	0	1
2 pieces hand-rail	0	0	16	0	0¼
2 steel ferrules	0	0	0¼	0	0½
4 ⅞-in. bolts	0	0	5½	0	1½
Shutting reversing-rods	0	0	0	0	5
8 steel keys for wheels	0	1	2	0	4
24 ⅝-in. bolts	0	0	12	0	7½
4 ¼-in. tap-bolts	0	0	0	0	0½
1 ⅝-in. ditto	0	0	0	0	0¼
2 handles	0	0	3¾	0	3½
16 ⅝-in. bolts	0	0	9¾	0	6¾
1 steel pin	0	0	4⅝	0	2
Shutting reversing-rods	0	0	0	0	5
4 keys for eccentrics	0	0	2	0	1
1 steel key	0	0	1	0	1½
1 guide plate	0	0	4½	0	3

	cwts.	qrs.	lbs.	Days.	Hrs.
2 $\frac{5}{8}$-in. stud-bolts	0	0	$1\frac{1}{4}$	0	3
1 $\frac{5}{8}$-in. ditto	0	0	$1\frac{1}{4}$	0	$0\frac{1}{2}$
2 $\frac{5}{8}$-in. tap-bolts	0	0	$0\frac{1}{2}$	0	$0\frac{1}{2}$
2 handles for piston	0	0	3	0	$3\frac{1}{2}$
2 plates for quadrant	0	0	$0\frac{3}{4}$	0	$0\frac{3}{4}$
4 $\frac{3}{4}$-in. bolts for suction-pipe	0	0	4	0	$1\frac{1}{2}$
4 $\frac{3}{4}$-in. ditto	0	0	4	0	$1\frac{1}{2}$
2 suction-pipe rods, 8 bolts	0	0	$3\frac{1}{2}$	4	$1\frac{1}{2}$
12 bolts	0	0	$1\frac{1}{2}$	0	$2\frac{1}{4}$
2 suction-pipe hangers	0	1	1	1	0
Suction-pipe ditto	0	0	0	0	7

CLASS.

Locomotives are of three classes:—First, the express, or single traction wheel. Second, or ordinary, has two wheels coupled. Third, or goods, has all the wheels coupled.

TRACTIVE POWER.

The locomotive is calculated by its tractive power, which is found by multiplying the area of cylinder in square inches by the mean pressure, and then by the length of crank in inches, and dividing the result by the radius of the driving-wheel, also in inches; 100 lbs. per square inch may be taken in all calculations, and cutting off in full gear at $\frac{3}{4}$ths of the stroke—or say a mean pressure of 90 lbs. per square inch. I will take a goods engine cylinders 16 inches in diameter, and 24-inch stroke, with six 5-feet wheels, all coupled:—

$$\frac{201 \times 90 \times 12}{30} = 7{,}236 \text{ lbs. tractive power.}$$

WEIGHT OF GOODS ENGINE.

Taking the adhesive power, per ton, at 300 lbs. for the rails in a greasy condition, is what must determine the weight of engine. Thus, 7,236 divided by 300 = 24·12 tons. Now engines of this class average 27½ tons, being 3·38 tons over—this is for the worst condition, or the rails in a greasy state: when the rails are dry, the adhesion will be about double.

DISTRIBUTION OF THE LOAD.

For Goods Engine, 27·5 tons.

		Tons.
Leading-wheels, multiply the total load by	·346 =	9·515
Driving-wheels ,, ,,	·36 =	9·900
Trailing-wheels ,, ,,	·294 =	8·085
Tons		27·5

For Passenger Engine, 19·5 tons. Second Class.

5-feet Driving and Trailing Wheels, coupled.

Leading-wheels, multiply the total load by	·30 =	5·85
Driving-wheels ,, ,,	·46 =	8·97
Trailing-wheels ,, ,,	·24 =	4·68
Tons		19·5

For Express Engine, 27 Tons.

7-feet Driving Wheel.

Leading-wheels, multiply the total load by	·41 =	11·07
Driving-wheels ,, ,,	·39 =	10·53
Trailing-wheels ,, ,,	·20 =	5·4
Tons		27·

For Express Engine, 18 Tons.

5 feet 6 inches to 6-feet Driving Wheels.

Leading-wheels, multiply the total load by	·3 =	5·4
Driving-wheels ,, ,,	·5 =	9·0
Leading-wheels ,, ,,	·2 =	3 6
Tons....		18·

Diameter of Cylinder and Stroke of Piston.

First Class.

	Inches.				
Diameter of cylinders	9	12	14	16	18
Stroke of piston	15	22	22	22	24
Diameter of driving-wheels ..	60	78	78	78	84

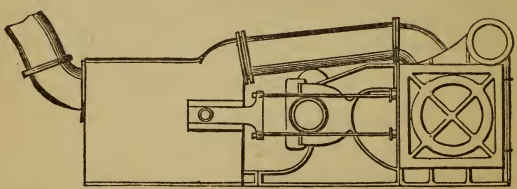
Second Class.

Diameter of cylinders.....	12	15	16
Stroke of piston	18	20	21
Diameter of driving-wheels	48	60	60

Third Class.

Diameter of cylinders.....	15	16	18
Stroke of piston	24	24	24
Diameter of wheel	51	60	60

The above are taken from practice.

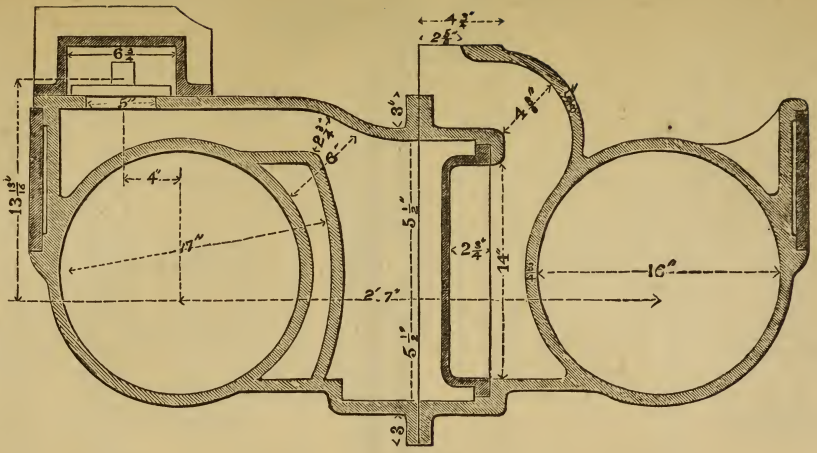


Direct-acting Engine of 400 H.P. collectively.

Cylinder Proportions.

Area of each steam-port,	divide the cylinder area in sq. in.			by 10
Area of exhaust-pipe,	,,	,,	,,	6
Area of each steam-pipe,	,,	,,	,,	9
Area of main steam-pipe,	,,	,,	,,	6
Area of blast-pipe at bottom, each		,,	,,	9
Area of blast-orifice	,,	,,	,,	13

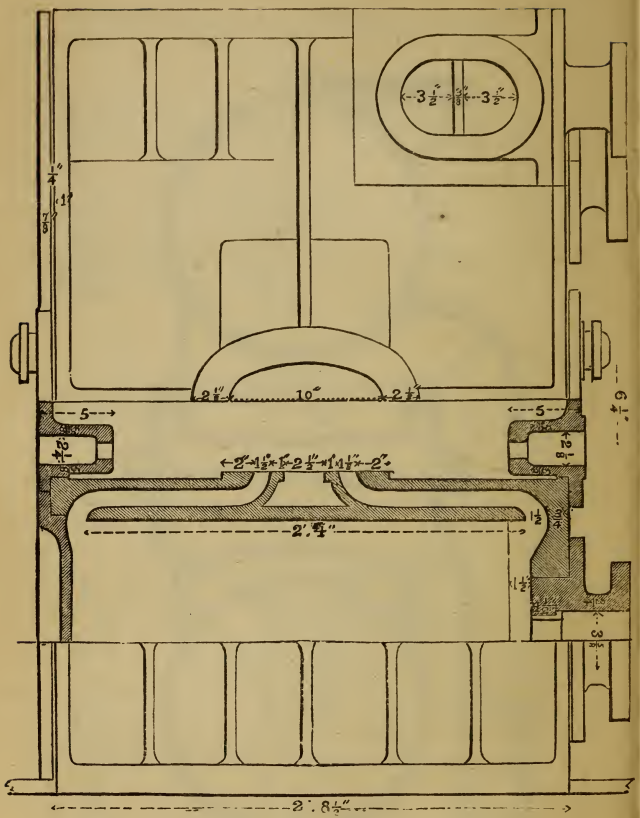
Cylinders.



Lap of Valve, 1″.
,, Exhaust, $\frac{1}{16}$″.
Lead, $\frac{3}{16}$″.

2′ 7″ Centres.

Diameter, 16″.
Inclination, 1 in 14·7″.
Stroke, 24″.



Cylinders.

LENGTH OF STEAM PORT AND OPENING BY VALVE.

To find the length of ports, divide the diameter of cylinder by 1·2. The opening by valve is found by multiplying the cylinder area into the speed of piston

in feet per minute, divided by the constant 10,000. Supposing it was desirable to obtain a speed of 45 miles per hour, having 16 inches diameter of cylinder, the stroke of piston 24 inches, and the driving-wheels 6 feet 6 inches—

$$\frac{5{,}280 \times 45}{60} = 3{,}960 \text{ feet per minute.}$$

Now divide 3,960 by the circumference of the wheel, and it will give the number of revolutions :—

$\frac{3{,}960}{20{\cdot}4}$ = say 194 revolutions; this multiple by 48 inches, or 4 feet for a revolution of crank, $194 \times 4 = 776$ feet speed of piston per minute :—

$$\frac{201 \times 776}{10{,}000} = \text{say } 15{\cdot}5 \text{ square inches of opening.}$$

THICKNESS OF CYLINDER.

Multiply the diameter of cylinder by the pressure, and divide the result by 120, which will give the thickness in sixteenths of an inch. Thus, for 18, 16, 14, and 12 inches in diameter, with 100 lbs. steam per square inch :—

$\frac{18 \times 100}{120} = \frac{15}{16}$ of an inch for 18-inch cylinder.

$\frac{16 \times 100}{120} = \frac{13}{16}$ „ „ 16 „

$\frac{14 \times 100}{120} = \frac{11}{16}$ „ „ 14 „

$\frac{12 \times 100}{120} = \frac{10}{16}$ „ „ 12 „

DIAMETER OF PISTON-ROD OF STEEL.

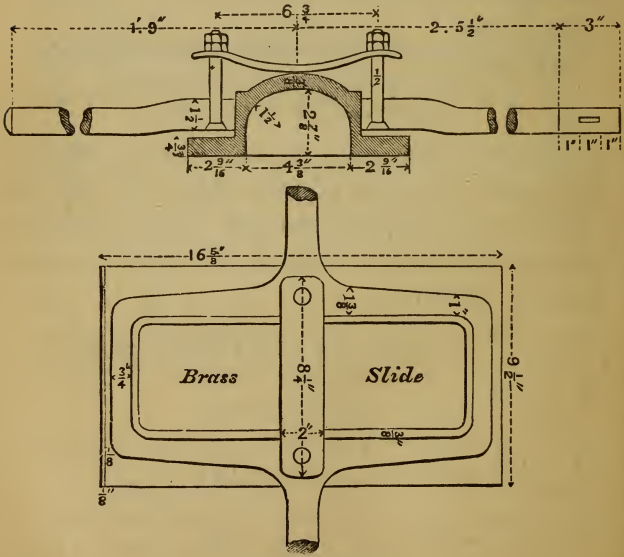
Multiply the area of cylinder by the pressure, and divide by 4,480, which will give the area of rod: thus, for 201 inches of cylinder, with 100 lbs. pressure per square inch area:—

$$\frac{201 \times 100}{4{,}480} = 4{\cdot}4 \text{ say, } 2\tfrac{3}{8} \text{ inches in diameter.}$$

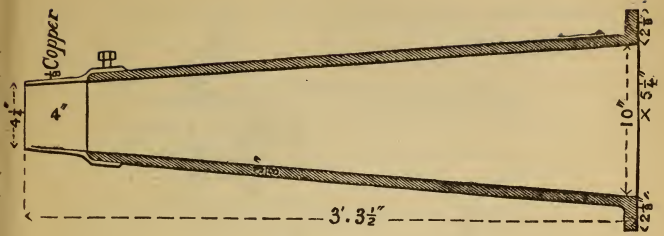
This gives ample surface for wear.

SLIDE VALVE AND ROD OF IRON.

To find the area of slide-rod, divide the area of valve-face by 100, and it will give the area of rod in square inches.



Slide Valve and Rod.



Blast-pipe.

FEED-PUMP. (*See next page.*)

Find the cubic contents in feet, in the cylinder, for an entire revolution; multiply the result by 6·6, being the number of cubic inches of water to a cubic foot of 100 lbs. steam; divide by the length of stroke of pump, and the quotient multiplied by 1·5 will give the area of pump. Thus, for 16-inch cylinder and 24-inch stroke—

$$\frac{1{\cdot}396 \times 4 \times 6{\cdot}6}{24} = 1{\cdot}53 \times 1{\cdot}5 = 2{\cdot}29 = \text{say, } 1\tfrac{3}{4} \text{ in.}$$

in diameter. This is when the pump-stroke equals that of the cylinder, and two pumps are always fitted. On very short lines the ordinary pump can be dispensed with, and a steam-pump or injector used instead.

MOTION-BARS, CROSS-HEAD, ETC.

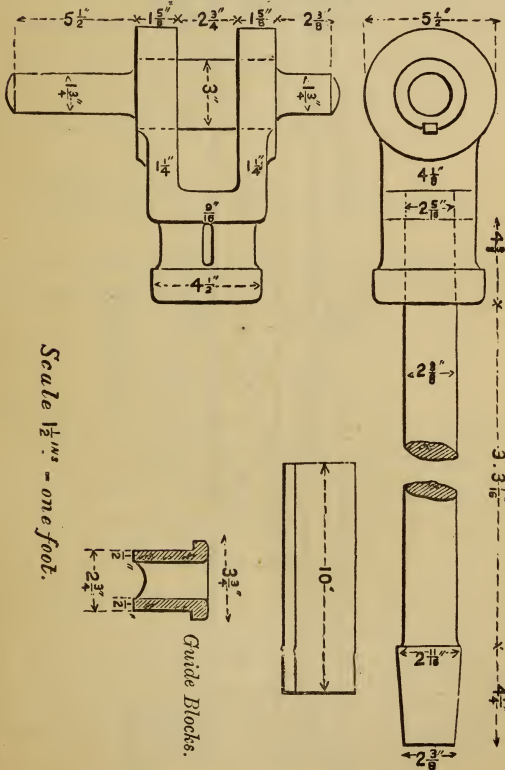
Double motion-bars are the best arrangement. To find the area of cross-head, divide the cylinder area

Ball 1" thick
Copper 10 wire guuge
Pump Ram.
Munts.
Scale 1" = foot

by 28. To find the area of slide-block pin, divide the cylinder area by 70. Thus, 201 cylinder area—

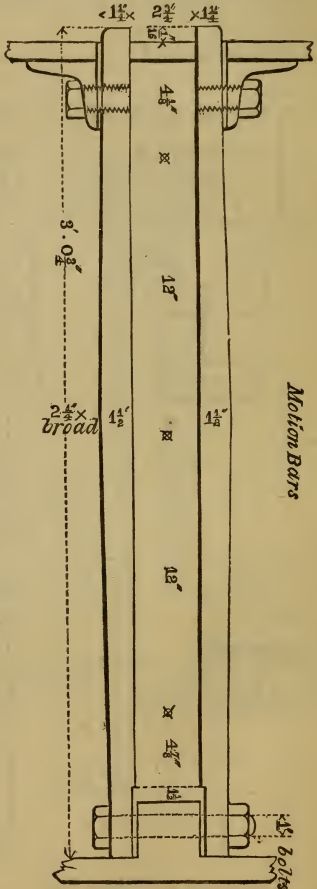
$$\frac{201}{28} = 7{\cdot}1 = \text{say, 3 inches diameter.}$$

$$\frac{201}{70} = 2{\cdot}8 = \text{say } 1\tfrac{3}{4} \quad ,,$$



Cross-head and Piston Rod.

Length of slide-blocks: multiply the cross-head by 3·3 = 9·9 inches. Thickness of brass blocks round pin $\frac{1}{2}$ inch: thus the depth = $2\frac{3}{4}$ inches. The width



of each motion-bar $\frac{1}{16}$ less than the diameter of cross-head = $2\frac{3}{4}$ inches. Thickness of the motion-bars as at middle $\frac{1}{2}$ of cross-head = $1\frac{1}{2}$ inches.

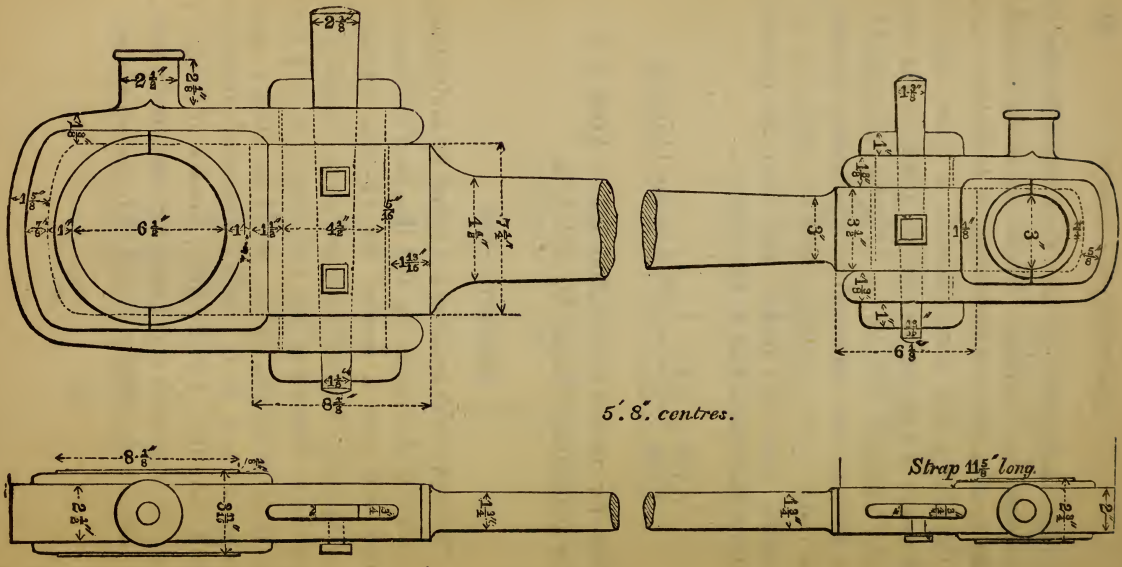
On taking the motion-bars as a beam, and an allowance of $\frac{1}{3}$ of the pressure on piston as the load = for a 16-inch cylinder, or 6,700 lbs., multiplied by the distance between supports, say 2·6 feet, dividing the result by the constant 1,338 for (iron), into the breadth, each 2·75 inches, and from the quotient extract the square root = the depth :—

$$\frac{6{,}700 \times 2{\cdot}6}{1{,}338 \times 5{\cdot}5} = \sqrt{2{\cdot}3} = \text{say } 1\tfrac{1}{2} \text{ inches.}$$

Bolts for motion-bars, 6,700 lbs. ÷ 4,000 ÷ 4 = area at bottom of thread for each bolt.

CONNECTING-ROD.

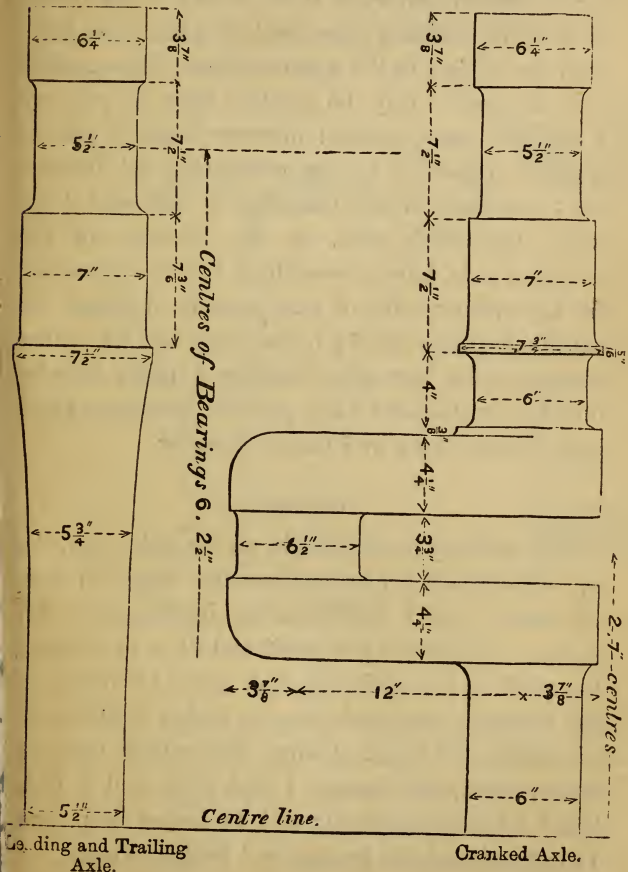
The area of the small end is found by multiplying the area of the piston by 100 lbs., and dividing by 4,000 will give a section for 16-inch cylinders, 3 × $1\frac{3}{4}$ inches for small end, and $4\frac{1}{2}$ × $1\frac{3}{4}$ inches for large end; breadth of jibs and cutters, $4\frac{1}{2}$ × $\frac{3}{4}$ inch thick; large straps, $2\frac{1}{2}$ in. × $1\frac{5}{8}$ in. thick; small straps, 2 in. × $1\frac{3}{8}$ in. thick; jibs and cutters for small end, $3\frac{1}{4}$ × $\frac{3}{4}$ inch thick; brasses at bottom, 1 inch for large end, and $\frac{3}{4}$ inch for small end; butts, $8\frac{1}{8}$ inches long, large end, and $6\frac{1}{8}$ inches small end.



Connecting Rod.

THE CRANKED AXLE, ETC.

The axles may be considered as rolling beams loaded and supported at the ends. For every ton on

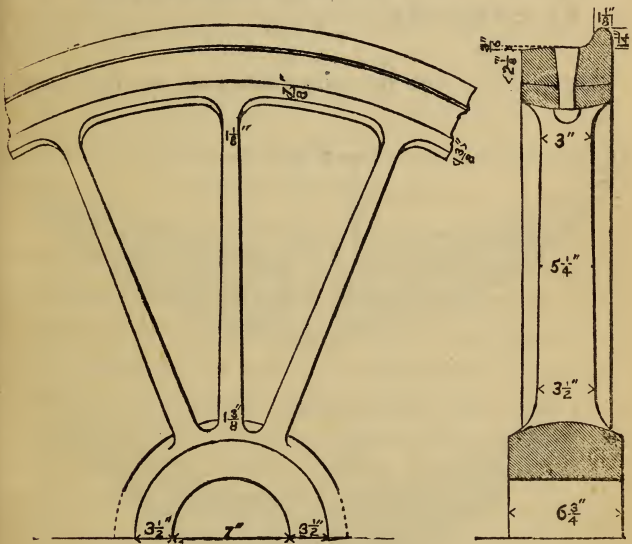


each axle make an allowance of 3·5 square inches of area, and the result will give the section at the crank-pin. Thus, for driving and coupled axles, for 9 tons on driver, $9 \times 3{\cdot}5 = 31{\cdot}5 = 6\frac{3}{8}$ inches at pin; for cranked axles, and for plain ones multiply the weight by 2·9 square inches. The cranked axle at centre may be smaller than at pin, say $\frac{1}{2}$ an inch less diameter: distance between jaws of crank is regulated by the connecting-rod brasses. Or to one-half of the diameter of axle add $\frac{1}{2}$ an inch; the crank sides, in the direction of the length of axle, have a breadth of $\frac{3}{4}$ of the diameter; for the ordinary size of axle, namely, 6 inches, the outside bearings are $7\frac{1}{2}$ inches long and $5\frac{1}{2}$ inches diameter; the horn-plate bearings 4 inches long by 6 inches in diameter; the part for receiving-wheel boss, 7 inches long by 7 inches diameter.

WHEELS.

For ordinary 5-feet wheels, all wrought iron, the eye of the wheel is 7 inches diameter; length of boss, $6\frac{3}{4}$ inches, and 1 foot 2 inches in diameter; flat spokes, 3 inches $\times 1\frac{1}{8}$ at point, and $3\frac{1}{2} \times 1\frac{3}{8}$ at boss; the pitch of the spokes at trod, about 11 inches on the average; the inside tire, $5\frac{1}{4}$ inches broad by $1\frac{3}{8}$ at middle, and $\frac{7}{8}$ inch at edge; the outside tires, $2\frac{1}{8}$ inches thick; the flanges, $\frac{7}{8}$ inch deep and $\frac{5}{8}$ inch broad for driving-wheel; and $1\frac{1}{4}$ inches deep, and $1\frac{1}{8}$ inches broad, for leading and trailing wheels.

For 3-feet wheels, all of wrought iron:—Eye, 6 inches diameter; length of boss, $6\frac{3}{4}$ inches; diameter of boss, $10\frac{1}{2}$ inches; spoke, 1 inch at point, $1\frac{1}{4}$ at boss, and 3 inches broad; the inside tire, $5\frac{1}{4} \times 1\frac{1}{8}$ inches, and the outside tire $5\frac{1}{4} \times 1\frac{1}{8}$ inches thick; the number of spokes. 10.



Wheels, 5 Feet Diameter at Trod.

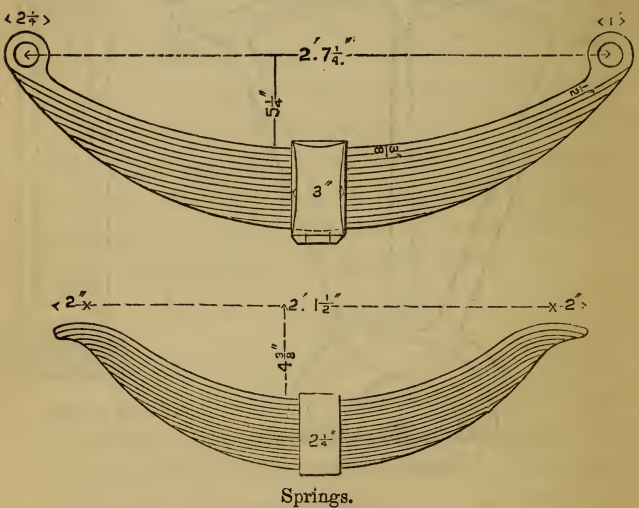
SPRINGS.

Ordinary springs, when loaded, are 2 feet 8 inches from centre to centre, and when unloaded, 2 feet $7\frac{1}{4}$ inches; and have a set of $5\frac{1}{4}$ inches from point of suspension to top of plates; the breadth of plates is usually 4 inches. To find the depth of spring, multi-

ply the constant 8·5 by the total load on axle in cwts., then by the length of spring when loaded in inches, dividing the result by the breadth of spring in eighth parts of an inch, and the square root of the quotient is the depth of spring in eighth parts of an inch; thus, supposing a load of 9 tons on a driving-axle—

$$\frac{8{\cdot}5 \times 180 \times 32}{32} = \sqrt{1{,}530} = \tfrac{39}{8} = \text{say 5 inches}$$

deep. This can be somewhat less, as the horn



Springs.

spring, when so fitted, takes a part of the load. Top plate, ⅜ inch thick at middle, and ½ inch at end; suspension-pins, 1 inch diameter; eye, 2¼ inches diameter; all the other plates about $\frac{5}{16}$ of an inch thick.

Leading Springs.

Top plates, $\frac{3}{8}$ in.; 20 other plates, $6\frac{1}{8}$ in. = $6\frac{1}{2} \times 4$ in. broad.

Middle Springs.

Top plates, $\frac{3}{8}$ in.; 13 other plates, $4\frac{1}{8}$ in. = $4\frac{1}{2} \times 4$,,

Hind Springs.

Top plates, $\frac{3}{8}$ in.; 11 other plates, $3\frac{5}{8}$ in. = 4×4 ,,

Horn Springs.

Top plates, $\frac{3}{8}$ in.; 13 other plates, $3\frac{3}{8}$ in. = $3\frac{3}{4} \times 2\frac{1}{2}$,,

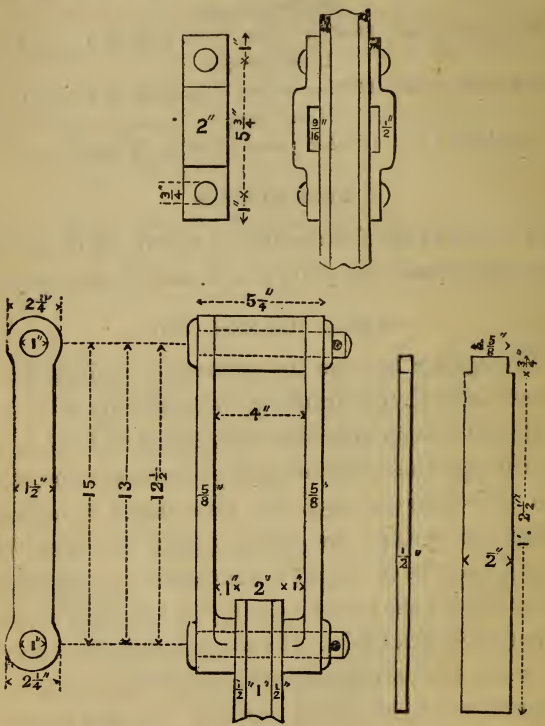
HORN SPRINGS

Are 2 feet $1\frac{1}{2}$ in. from centre to centre, $3\frac{3}{4}$ deep, and $2\frac{1}{2}$ inches broad; top plate $\frac{3}{8}$ inch, and 13 other plates.

SPRING HARNESS, ETC.

The spring harness for passenger engines, when placed above the framing, is generally a single T-shaped tension-rod, with screwed end and nut, passing through the centre or wood part of the frame, with two side-links on each for attachment to spring. When the springs are placed under the axles, the spring harness is simply a box-coupling with inside rod and nut; the leading-springs, when not coupled, have merely side-links. The compression-pins, taking the whole load, are sometimes round or flat, to suit the different arrangements of framing. To find the area at the bottom of the thread for tension-rods, divide the total weight on the axle by 4, and then by 2, and the quotient will be the area; thus, for 9 tons, $9 \div 4 = 2{\cdot}25 \div 2 = 1{\cdot}12 =$ adding depth of thread $1\frac{3}{8}$ inches diameter for each: the compression-pin of steel, same diameter. When fitted with side-links,

with spring-pin 1 inch diameter, the side-links are $1\frac{1}{2} \times \frac{5}{8}$ of an inch thick.



Spring Harness.

FRAMING.

The framing for modern engines is now separate and distinct from the boiler. The object of this arrangement is to simplify the construction, the boiler merely resting on the framing with suitable

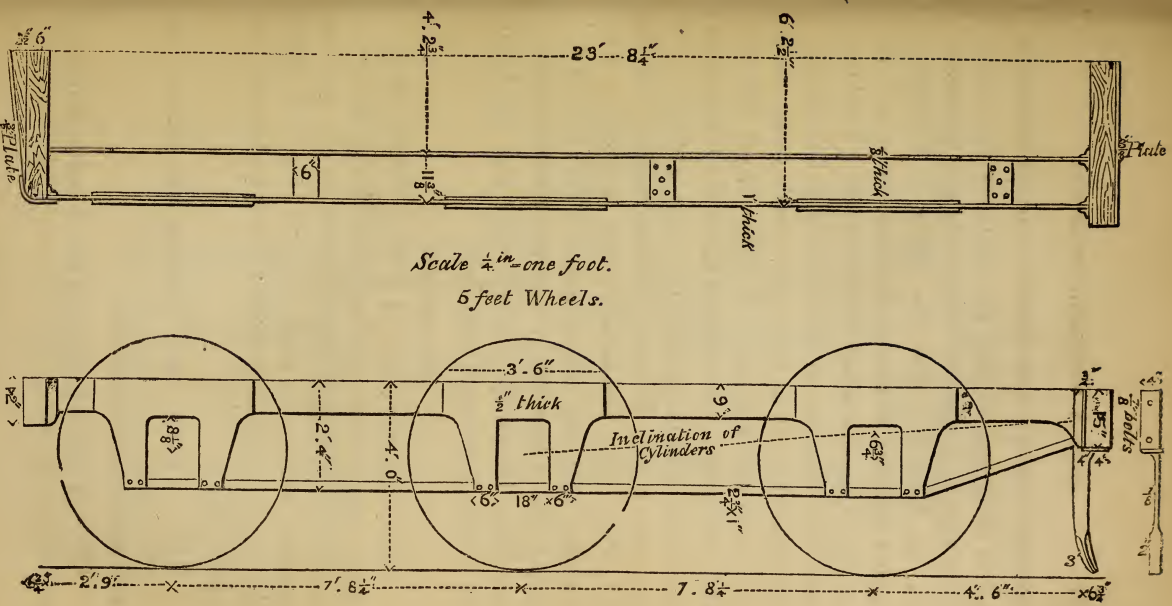


Plate
Plate
1" thick
Scale $\frac{1}{4}$ in = one foot.
5 feet Wheels.
Framing.
M 3
$\frac{1}{2}$" thick
Inclination of Cylinders
18" × 6"
8 Bolts

brackets, and the horn-plate is carried the entire length of frame, so that the cylinders are merely bolted thereto, instead of being fitted into the smoke-box, as formerly; thus the boiler is allowed to expand without straining the machinery, and the framing takes the whole strain of itself. The horn-plate, for a 16-inch cylinder locomotive, has a section of 9 inches by $\frac{7}{8}$ of an inch; the outside frame, when fitted with oak between, is 5 inches broad over all, with side-plates $\frac{7}{16}$ of an inch thick, the frame-plate and axle-frames being all in one, so as to make a neat and clean finish. However, in some engines, such as for goods traffic, the outside frame is simply a bar 9 inches by 1 inch throughout, with side-plates for axle-boxes, $\frac{1}{2}$ inch thick, strongly riveted thereto; the buffer beams, 15 × 6-inch oak; and end beam 12 × 6 inch, strapped with iron.

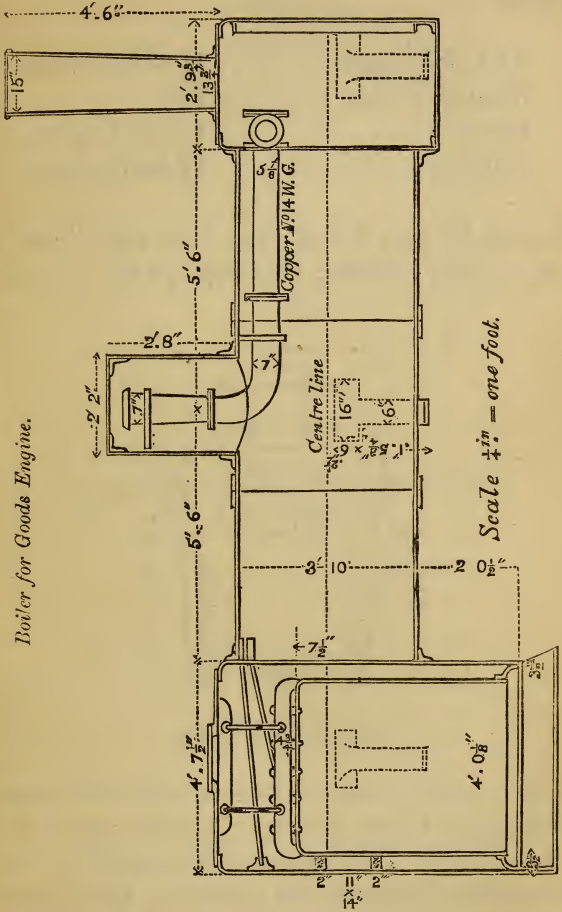
THE BOILER.

To find the cubic feet in body of boilers for passenger engines (for moderate speed), divide the cubic contents of both cylinders in inches by 80, and the quotient will be the cubic contents of body in cubic feet; thus, for 16-inch diameter of cylinder, and 21-inch stroke—

$\frac{8,442}{80} = 105{\cdot}5$; and supposing the body to be 10 feet long, then we have

$\frac{105{\cdot}5}{10}$ = say 10·5 area, or 3 feet 8 inches diameter.

The inside fire-box for this size is 3 feet 5 inches by

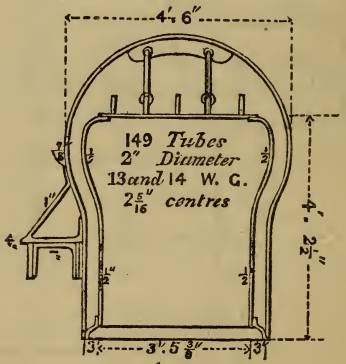


3 feet 5 inches, by 4 feet deep from top of bar; and

the top of fire-box 3 feet 8 inches by 3 feet 5 inches.

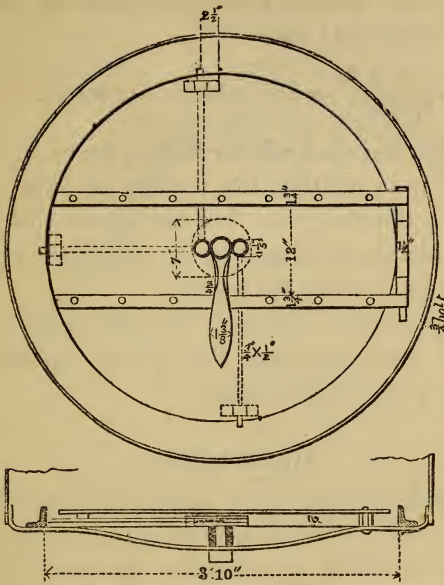
Area of fire-grate . .	11·66 square feet.
Number of tubes . .	170.
Length	10 feet 4 inches.
Diameter . . .	$1\frac{3}{4}$ inch outside.

Outside fire-box, 4 feet long; from top of ditto to top of body, 4 inches; total depth, 6 feet 2 inches.



Boiler for Goods Engine.

Width, 4 feet 5 inches at top, and 4 feet at bottom. Smoke-box, 4 feet 5 inches diameter, and 2 feet 7 inches long. Tube surface, 802 square feet; fire-box surface, 68 square feet; chimney, 13 inches at top, 14 inches at bottom.



Smoke-box Door.

HEATING SURFACE AND FIRE-GRATE.

Supposing a speed of 25 miles per hour is desirable, with, say, 16-inch cylinders, stroke 21 inches, and 5 feet 6 inches diameter of wheels, with 11·6 square feet of fire-grate—

$$\frac{5{,}280 \times 25}{17{\cdot}3} = 7{,}630 \text{ revolutions per hour.}$$

Now, 7,630 × 7 = 53,410 cubic feet of steam for both cylinders, at a mean pressure of, say, 90 lbs. per

square inch, requiring 6 cubic inches of water to raise a cubic foot; thus—

$$\frac{53{,}410 \times 6}{1{,}728} = 185 \text{ cubic feet of water.}$$

Now, the recognised rule for finding the total heating surface is to multiply the number of cubic feet of water by the fire-grate, find the square root of the result, and then multiply by 21, which will give the surface for 25 miles per hour:—

$185 \times 11{\cdot}6 = \sqrt{2{,}146} = 46 \times 21 = 966$ square feet of heating-surface, this giving out the full tractive power of the engine.

SAFETY-VALVES.

To find the diameter of safety-valves, two fitted, multiply the number of square feet of heating surface in the fire-box by 144, dividing the result by 450, and one-half of the quotient is the area in square inches for each valve:—

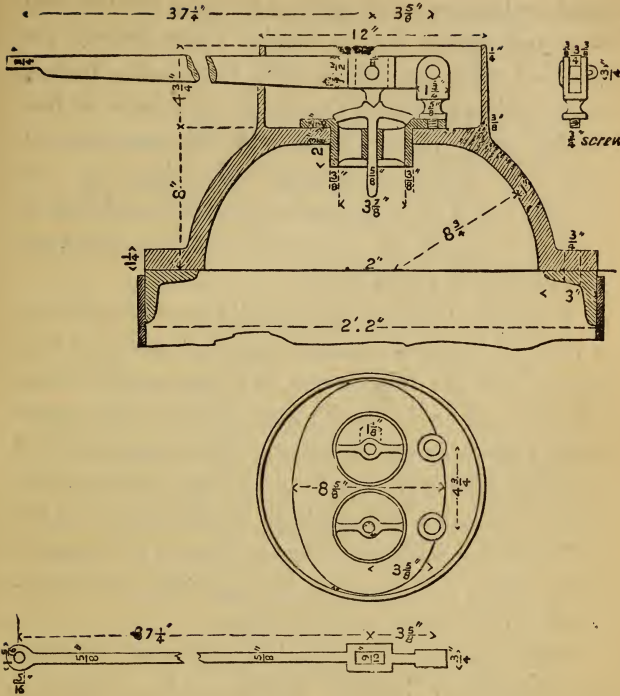
$$\frac{68 \times 144}{450} = 21\,7 \div 2 = 10{\cdot}8 = \text{say } 3\tfrac{11}{16} \text{ diameter,}$$

with 100 lbs. spring balance, 10·679 being the area,

$$10{\cdot}679 \times 100 = 1{,}067{\cdot}9 \text{ lbs. on valve.}$$

Now, taking the distance from stud to centre of valve to be 3·5 inches—

$$\frac{1{,}067{\cdot}9 \times 3{\cdot}5}{100} = 37{\cdot}37 \text{ inches from stud to spring balance.}$$



Safety Valve.

FURROWING AND PITTING IN LOCOMOTIVE BOILERS.

Some theorists attribute furrowing to the expansion and contraction of the boiler, inducing a bending and unbending of the plates; if so, then the outside of the plates would show an abrasion similar to the end plates of the smoke-box, as with

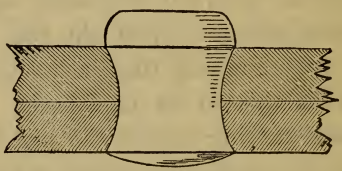
inside cylinders, or simply to a straight strip of iron bent and unbent by the hand. These furrows are observed with lap joints, with butt joints having inside strips, but when the strips are outside no furrowing takes place. Now, with this statement, I hold this theory of bending and unbending of a circular boiler to be perfectly erroneous, and look to natural laws for an explanation of the furrowing and pitting of steam boilers.

Mountain torrents very rapidly wear the bed of a river of the most compact material, and it is well known that the bilge-water in a ship rapidly wears off the rivet heads, by the mere friction of the water rolling forwards and backwards. Were water allowed to drop on an iron plate, drop by drop, pitting would follow, corrosion taking place, and the impact of the falling water washing away the rust as it formed—thus eating into the iron very quickly, more especially on soft spots of the surface.

Now, what is the mechanical action of the water in a locomotive boiler? I take it to be a racing of the particles from the fire-box to the smoke-box end, and as the steam is generated from the tubes, a partial explosion takes place in all directions, carrying the particles of water along with it. I am not so certain that the impact of the water propelled by the steam generated by the tubes acting on the surface of the boiler does not, in a great measure, account for pitting. When corrosion takes place, the

incessant impact of the water on the soft spots of the iron must wash off the rust as it forms, leaving the surface always raw, as it were (assisted in some cases by galvanic action). The boilers generally show the centre of the furrow about one inch from the lap joint. I will endeavour to give an explanation of this. Noticing pieces of wood floating on the surface of our silent Thames when the river had attained its greatest downward velocity, I was quite struck by observing at the piers of the bridges that the pieces of wood never came in contact with the pier, but invariably took a rapid current about one foot from the pier, and were carried away more rapidly than in the centre waterway. How is this to be explained? I take it that the water flowing against the pier is repelled, the same as the sea dashing against a breakwater is thrown back again, and being met with a downward current, and the meeting of the waters, I will say, induces a rapid current one foot from the pier. Those interested can make this observation for themselves by simply looking over, say, Westminster Bridge, and observing materials floating on the surface. I am just going to state that this phenomenon is the cause of the furrowing of locomotive boilers. Where a boiler is made perfectly cylindrical, with butt joints and the strips outside, no furrowing is observed; with the strips inside, or with lap joints, furrowing takes place. Now, in my

opinion, the strips and lap joints are the obstructions, as in the piers of a bridge, causing these furrows; the steam generated from the tubes, shooting the water against the edges of the plates, is repelled, and the racing of the water from the fire-box end causes a rapid current to flow parallel with the joints, this upward and repelling and onward action of the confined water inducing more friction, and, consequently, keeping this part of the boiler in a raw state, making it more subject to corrosion and galvanic influence. With these opinions I consider,



when the edges of the plates are placed downwards, they are more liable to form furrows. Some bevel the edges of the plates, which I consider will tend to lessen this evil, but cannot imagine it would be easily calked, as it is very difficult to calk a knife-edge. The best cure is by making outside strips strong enough with butt joints and a proper form of rivet, which I maintain is a double counterlap; thus we shall have as strong a boiler with no furrowing, which must tend, in a great measure, to reduce the number of boiler explosions. The drawing shows the rivet I would adopt for lap and butt joints. A

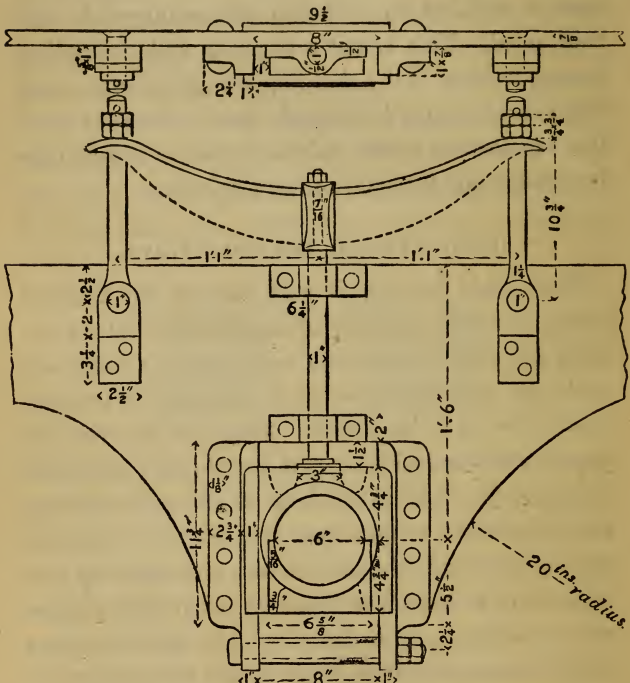
curved countersink is, I consider, the strongest form, as the iron is less distorted. Part of the head of rivet is retained to resist the force of impact from the riveting hammers; and it is evident that if the head is reduced by corrosion the countersink will hold good. This is not a bending and unbending theory, neither is it a bulging one, as in some cases these theories may hold good; but at the same time the mechanical action of the water in either case I consider rapidly deteriorates the boiler.

INSIDE BEARING AND HORN-PLATE.

The inside bearing is only adopted for cranked shafts, or inside cylinder arrangements, where plain axles are used; for outside cylinders it is dispensed with, the only object being to support the cranked shaft close up to the cranks. Some makers even dispensed with the inside support, but the axle soon gave way, and they had to fall back on the original plan, as the flexional strain, combined with the torsional action, soon made the axle break; consequently it is imperative to have four bearings for inside cylinder arrangements. This bearing for goods engines simply moves in guides fitted to the horn-plate, but for fast engines the guides are movable, or have a wedge arrangement, so as to adjust the wear, or prevent the knocking action imparted by the rapid shuttle movement, as it were, of the pistons.

The annexed woodcut shows the general arrange-

ments, with spring, harness, and all complete. The horn-plate in modern engines forms part of the main framing, running the entire length, and bolted to the front and aft beams, thus taking part of the



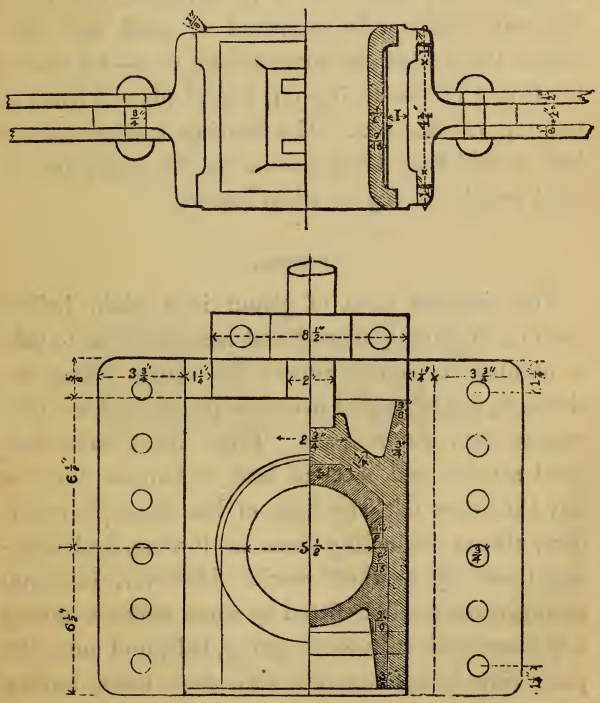
Inside Bearing and Horn-plate.

hauling strain, this being a great improvement over the former plan of fixing the horn-plate between the fire-box and smoke-box, the framing being considerably strengthened; and the boiler being

independent in a measure from the framing, the machinery is not so much strained either from the hauling or buffing action of the machine.

AXLE-BOXES.

The axle-boxes are strong cast-iron frames, fitted with a top bearing of brass; the bottom part being



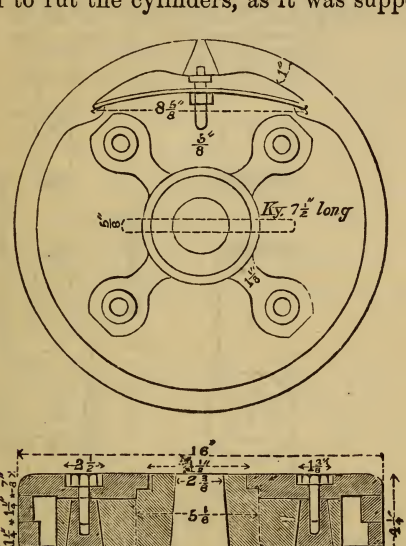
Axle-box.

cast iron, accurately fitted and held in position with side-flanges, the lower portion having two round pins, through and through the axle-box, so as to prevent it dropping out. The axle-box has a recess at sides, accurately planed, working into a wrought-iron or cast-iron guide, fixed to the main framing of engine with $\frac{3}{4}$-inch rivets. The drawing shows a guide of wrought iron, suited for a plate-frame; but when the main framing is composed of wood and side-plates, the guides are made of cast iron—for taking the thrust of the spring-pin a steel plate is fitted to the top of axle-box. The bearing surface on top half should have 18 square inches for every ton, or total weight of engine when loaded.

PISTON.

The simplest form of piston is a plain hollow casting, accurately turned, and recessed so as to take a number of steel rings; the rings being cut through, are expanded over the piston, and are thus sprung into the recesses. Those rings have done good service, and seem to bear, so long as there is any thickness left, the heat of the steam in cylinders, always expanding them as it were, and keeping them up to their work. However, cast-iron spring rings are still fitted by some makers, having a V piece and adjusting spring, bolt, and nut, the junk ring being secured with four bolts, having brass cones in piston. It is very obvious this piston

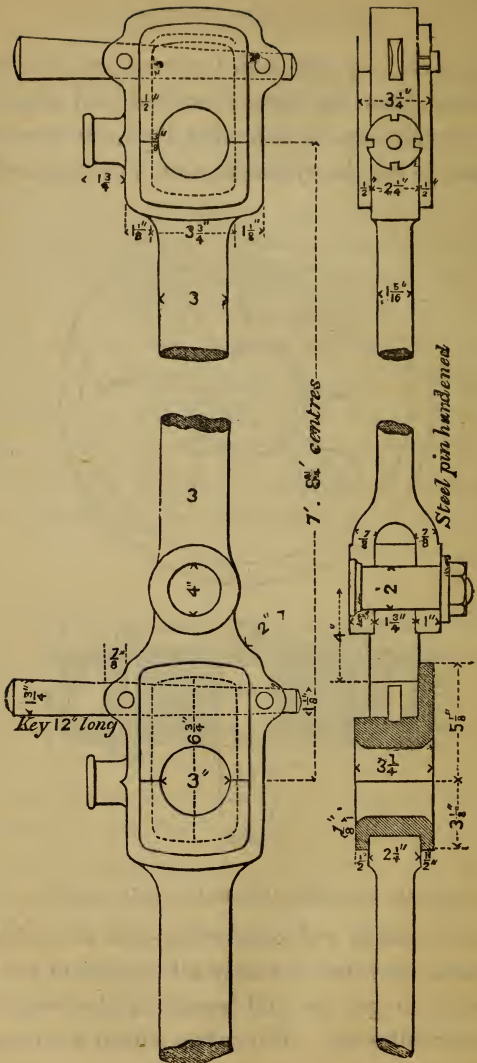
is expensive to get up, and the wear and tear must be greater than the former method, and when the metal in cylinders is somewhat hard, the steel does not seem to rut the cylinders, as it was supposed.



Piston.

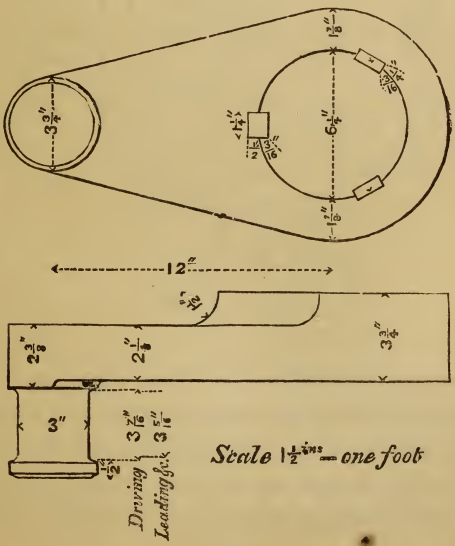
OUTSIDE CONNECTING-RODS AND CRANK.

Outside cranks and connecting-rods for coupling the wheels are fitted to nearly all engines of modern date, so as to get the full benefit of the weight of engine for adhesion. When two wheels are coupled



Outside Connecting Rod.

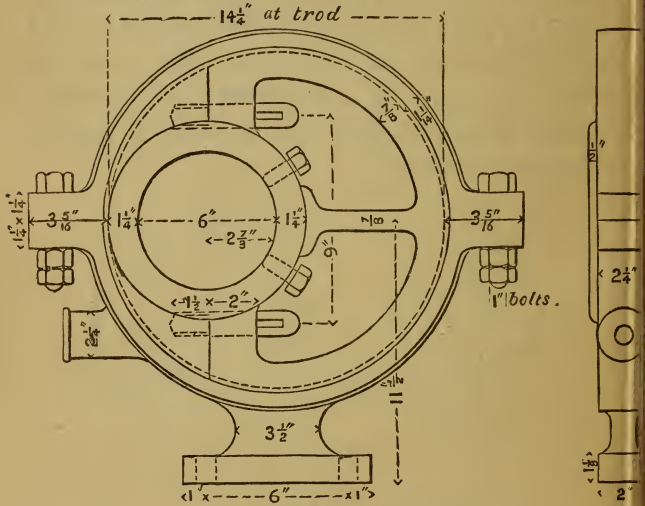
the rods are simply fitted with end brasses and cutters; but when three wheels are coupled, between the driving and trailing axle a pin and joint are introduced: this is required so as to allow the springs to work freely, without injury to the rod. The drawing gives the usual proportions adopted. The brasses are well fitted and keyed up with a single cutter, having two set screws in each, for preventing it working loose; the lubricators are forged on, and fitted with spring and dash-piece. The cranks are forced on, or put on hot, and shrunk on with a plentiful supply of water, and are held in position with three steel keys.



Outside Cranks.

ECCENTRICS, RODS, LINK, ETC.

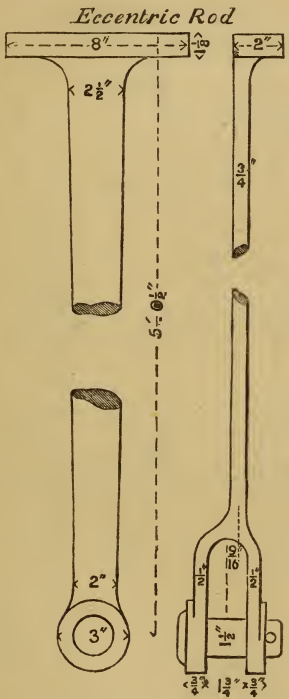
The double eccentrics and link-motion are, we may say, the controlling power in the locomotive; by them the machine can be made to go forward or backward, and, as a means of working expansively, the simplest and most efficient as yet introduced. The eccentrics are in two pieces, having two pin studs



Eccentric.

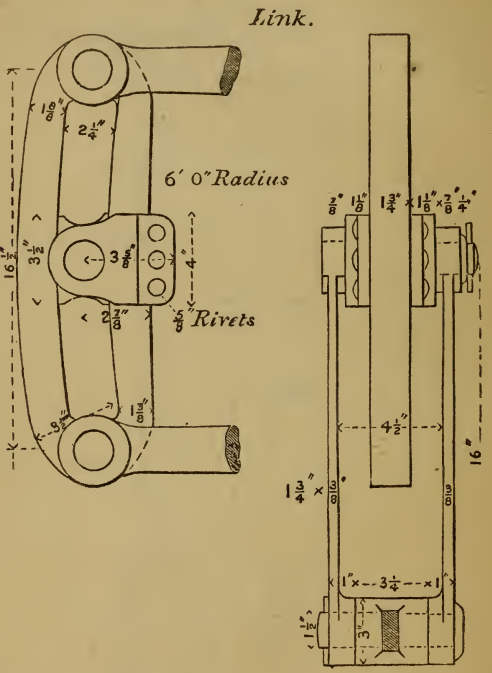
and cutters for joining the halves together, and two cupped stud-bolts for preventing the eccentric turning on shaft, as likewise having a keyway sunk in shaft. The straps are of brass, bolted together in the usual manner with jam-nuts, split pins, &c.

The most approved form of link is the solid slotted bar, suspended at middle, and the eccentric rods at end; the sliding-block and end-pins are of steel, and the link is casehardened, so as to get the greatest



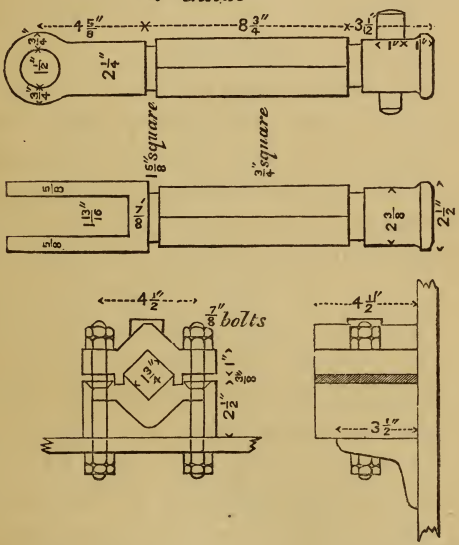
amount of wear, as in dirty weather the sand, or in dry weather the dust, finds its way amongst the rubbing surfaces. There are generally two suspending links, one on each side, with levers con-

nected to reversing-bar, supported with suitable brackets bolted to the main framing. On the outer end of bar is a lever, with reversing-rod passing along to the back of engine on platform, where the



reversing-rod and handle are fixed, the quadrant for reversing-handle being notched with a number of square slots, for suspending the link at any part of fore or aft movements, thus cutting off the steam at

parts of the stroke as may be determined on, or shutting off the steam from cylinders, the reversing-handle being placed vertically; the link is suspended at the middle of its length; thus no motion, or very little, is given to the valve. The proportions given by drawings are those usually adopted,

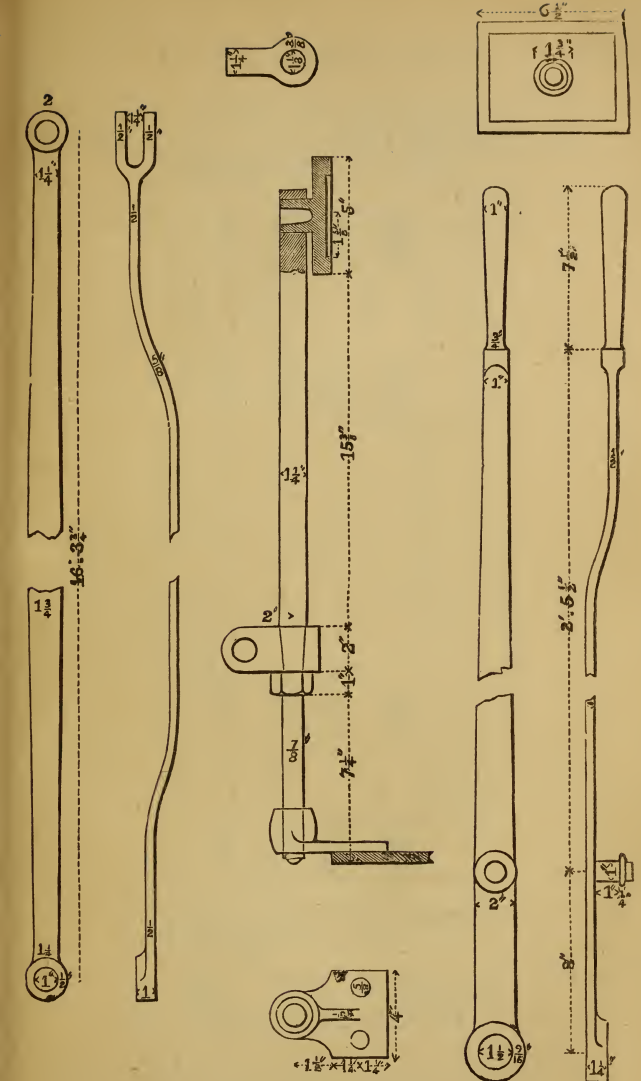


but may be varied by size of valve, &c. The link is connected direct on the valve-rod, having a V guide-bar and guide-block bolted to the after steadiment for taking the main motion-bars, the valve-rod passing through the stuffing-box on steam-casing, and guided at the front end with a suitable socket

or stuffing-box. For taking the valve the rod has a flat hoop forged thereon, with spring on back and set screws, for pressing the valve up to the face. Some arrangements of valves are simply an open frame, with a ring on the back, working steam-tight on the valve-casing cover; by this means the valve is relieved from the steam pressure.

REGULATOR.

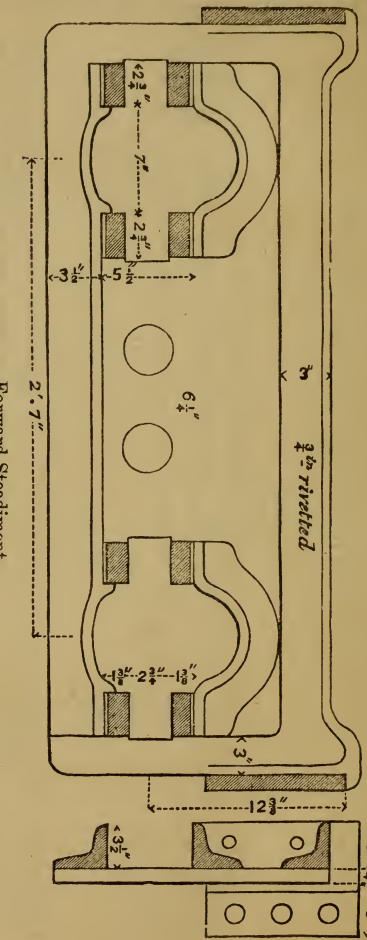
There are various forms of valves for regulating the supply of steam to the valve-casing. Round valves, working on a centre pivot, were much used at one time; but this plan was found to wear unevenly, from the obvious reason that the circumference of the disc moved through greater space than at the centre of valve; the valve now generally adopted being a plain flat plate, similar to a sluice-valve, working in a separate valve-chest on cylinder, the valve-rod passing through a gland, and guided at the extreme end, having a short arm keyed on so as to take the rod, the rod being actuated by a handle on starting-platform, alongside of the reversing-handle, with a suitable quadrant, fitted to the main quadrant for reversing-handle, so that the engine-driver has each in hand at one and the same time; by this means he can rapidly turn off the steam and reverse the gear at a moment's notice, the valve being fitted as near the main slide-valves as convenient.



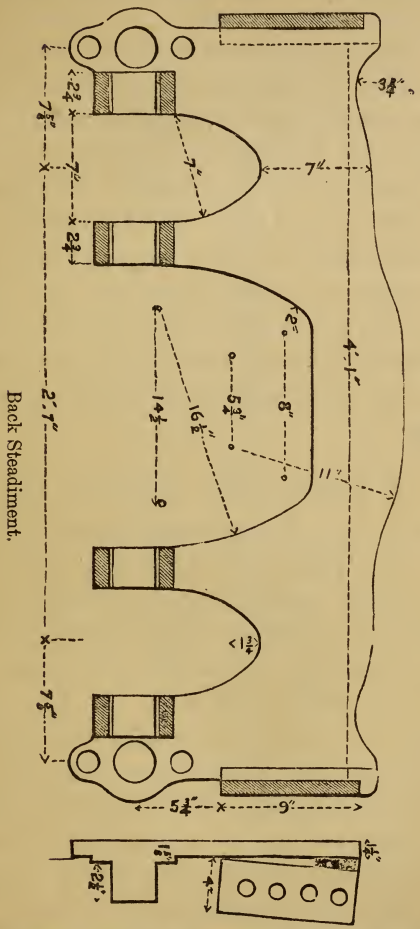
Regulator and Handle, &c.

MOTION-BAR STEADIMENTS.

The motion-bars are secured in various methods.



When of the double type, lugs are cast on each side



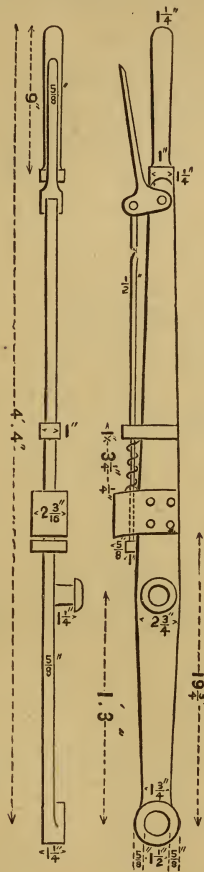
of the piston-gland, to which they are bolted, the

back end being supported with a wrought-iron steadiment between frames, and bolted thereto, having lugs forged on the steadiment for taking the motion-bars. In the arrangement illustrated there are two steadiments to which the motion-bars are attached—the forward one is made of plate iron, having angle-iron webs all round, to which the V slide-guide is bolted at the centre of steadiment; the back motion-bar is a solid forging, having flanges for securing it to the side-frames, with lugs for motion-bars, and at each end a projection, with suitable holes for taking the end of pump to which it is bolted, the other end being bolted to the main framing.

STARTING-HANDLE, QUADRANT ETC.

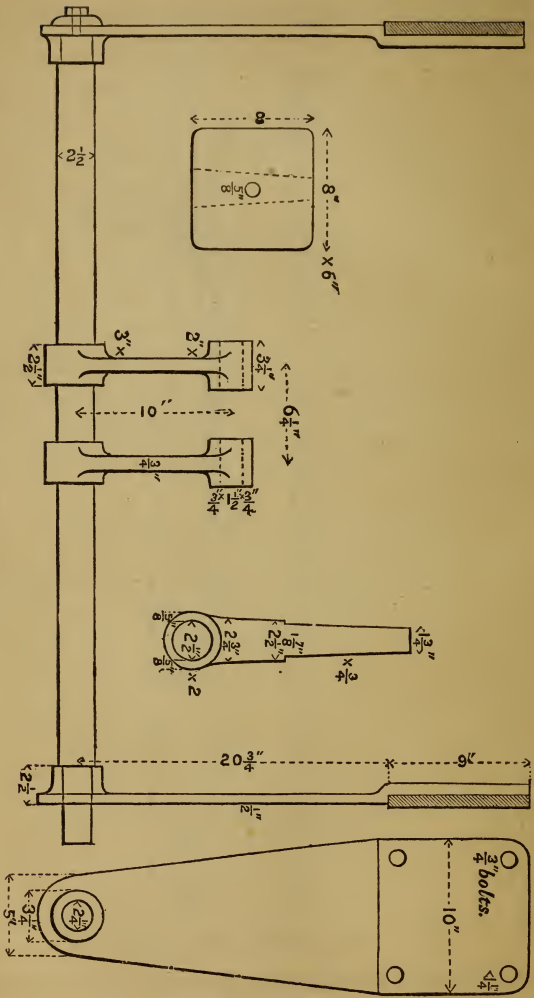
The starting-handle is generally fitted to the right hand of the platform, looking forward, the driver having better command in that position, although the left hand of platform would be the best place, as regards receiving signals from the guard of the train. The bottom joint of the reversing-handle is attached to the quadrant, having a stop and thumb-lever, spring, &c., suitable slots being cut in the quadrant to suspend or keep in position the link-motion, thus cutting off at any part of the stroke that is desirable, the reversing-handle being fitted with a rod, that passes forward to lever, on the weigh-bar shaft, this shaft carrying the necessary

reversing-links, and being bolted to the main framing



Starting Handle and Rod.

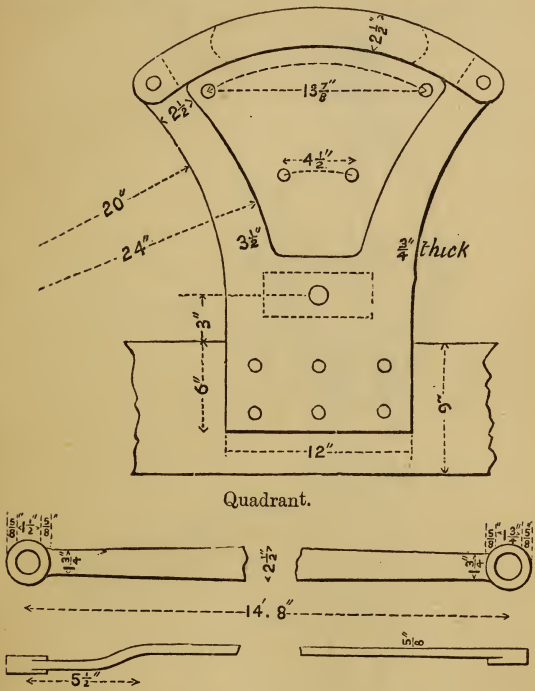
with suitable wrought-iron brackets. On the weigh-



Weigh Shaft, Bracket, &c.

Starting Gear.

shaft is fitted a separate arm, having a weight so as to balance the link, rods, &c., thus making it easier to reverse the motion: of course the steam should



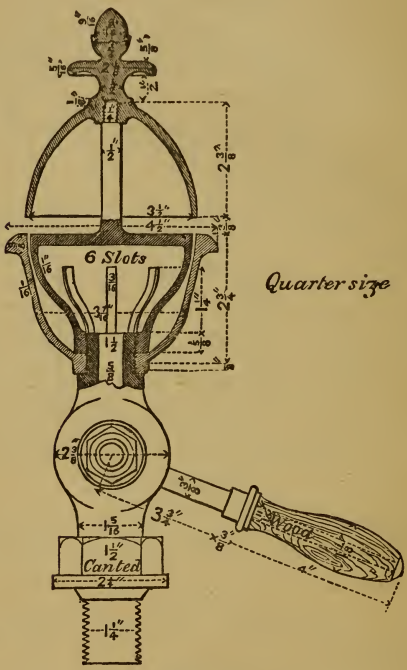
Quadrant.

always be shut off from the back of slide-valve before doing so.

GENERAL DETAILS.

To increase the adhesion of the wheels on the rails when they are in a greasy state, sand-boxes are

fitted; the most convenient place is on the top of barrel of boiler, in the form of a dome, with lid on top, with suitable valves, levers, rods, &c., carried along to



Whistle.

starting platform. The sand-box is fitted with two pipes, carried down in front of the driving-wheels; thus with one movement of handle both rails are sanded simultaneously.

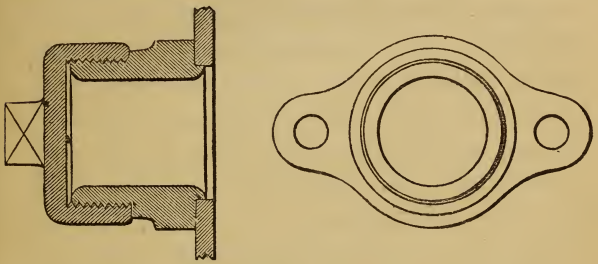
The steam-whistle is placed at the back end of outside fire-box, so as to be easily reached; it consists of a cock, in connection with an annular chamber, the steam escaping through a narrow annular aperture, blowing against the edge of the bell, thus producing a sharp whistle, similar to the sound caused by the mouth blowing or whistling against a sharp edge of metal. There are two bells or whistles fitted, one being deeper than the other, producing a fuller sound; it is only used to attract the attention of the guard, so as to give him warning to turn on the brake in his van, &c.

The usual water-gauge is fitted to the side of outside fire-box; it consists of a round glass tube, with index-plate, for showing the height of water above the crown of the fire-box. As the glass is liable to get broken, there is a separate brass casting, in the form of a tube, fitted with two cocks, one to indicate a sufficient quantity of water, and the other, when it blows steam alone, shows the water is too low. There is likewise one cock at top and bottom, to turn the steam and water off should the glass gauge get damaged. The usual mode of attachment to the side of fire-box is by cast-iron hollow distance-pieces jointed to the boiler, tapped at the other end to receive the screwed projection on the brass casting. When the gauge is fitted to the back end of fire-box, the cast-iron distance-pieces can be dispensed with. The "Bourdon," or steam-

pressure gauge, is fitted to a plate on the top of fire-box, having a U -shaped wrought-iron pipe from the boiler. By this simple means, the water or oil, lodging or placed in the bend, keeps such delicate contrivances perfectly cool. The "Bourdon" steam-gauge is certainly the most elegant contrivance yet introduced. The inventor, in the course of manufacturing a coil, or copper worm for a still, perceiving that one side became flattened, applied water-pressure to restore the cylindrical shape, and to his astonishment the coil assumed a straight form. Such is a law of nature—that bends under pressure have always a tendency to assume a straight line. So his gauge simply consists of a bent oval tube, fixed at one end, and in communication with the steam in boiler; the other end is filled up, and has a connecting-rod attached to a lever, with toothed quadrant and pinion, the pinion-spindle carrying the index-handle, which revolves in the centre of a disc-plate, marked so as to indicate the pressure required, the whole being enclosed in a suitable box. There is a cock fitted to some convenient part of the fire-box, termed the heating-cock, for blowing the steam into the tender, when the safety-valves blow off, thus heating the feed-water.

A blow-off cock is fitted to the bottom of fire-box, for blowing all the water out of the boiler. Sludge-doors are also fitted at the bottom corners of fire-box, as likewise on a level with the crown of

inside fire-box, so that a jet of water may be thrown in, washing away any sediment collecting. A good form of sludge-door is simply a brass pipe-piece with flange and screw, having screwed cap, similar to a water hydrant.



Sludge Hole. Quarter size.

The "pet"-cock is fitted to the feed-pipe delivery-box, so as to blow off any steam that may collect between the suction-valve on pump and the check-valve: it is turned by a rod, having a handle worked from the platform. At each end, at the bottom of cylinders, cocks are fitted to blow off any water that may collect in the cylinders from condensation, having suitable mechanism for working them from the starting-platform.

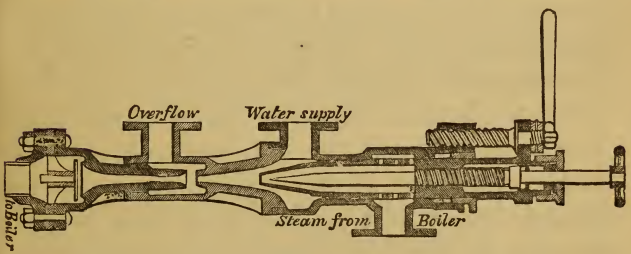
All modern engines are fitted with a "cab," for protecting the driver and fireman from the cold: they are furnished with glass bull's-eyes, so as to be able to see ahead. All the necessary hand-rails must be placed round the engine, and the wheels protected with dash or splash plates, for preventing

the mud carried round by the wheels flying about, and likewise as a security against accident in traversing the side foot-plates when passing along to the grease-cock for cylinders, fitted to the top of smoke-box, as also for oiling the machinery in motion.

A stud for forward-lamp is placed at the front of smoke-box. On the buffing-beam, or front beam of engine, suitable buffing-springs are fitted, so as to lessen the shock when coming in contact with wagons or carriages on the line, in the act of shunting, &c. A drag-chain is likewise fitted to the centre of the beam.

Thus I have considered the principal details. However, an auxiliary engine or steam-pump is sometimes fitted, for pumping water into the boiler while standing. The benefit of such an arrangement consists in the pump being able to throw water into the boiler at very nearly the boiling-point, or 212°. The steam-pump is completely eclipsed by the elegant contrivance termed the "injector." The drawing on the opposite page almost explains of itself the action of the apparatus. The central cone-spindle is made adjustable, so as to allow the exact quantity of steam to pass, while the outer cone-pipe can also be adjusted for allowing the necessary quantity of water to pass around the annular space left between it and the outer casing. As this instrument works best with cold water, I am inclined to think the water is simply injected into the boiler by

the velocity it acquires by the steam and atmospheric pressure. Were the water in the tank at the boiling-point, and the steam turned on from the boiler, no water could be injected into the boiler from tank; but were it comparatively cold, the water would flow in. Now, I think this is to be accounted for by the steam rushing against the cold water, forming a partial vacuum, thus creating a circuit, that would be *in equilibro* were the steam forcing through warm water; but as the steam impinges against cold water, forming a hollow cylinder *in vacuo*, the atmospheric pressure comes to bear, and



The Injector.

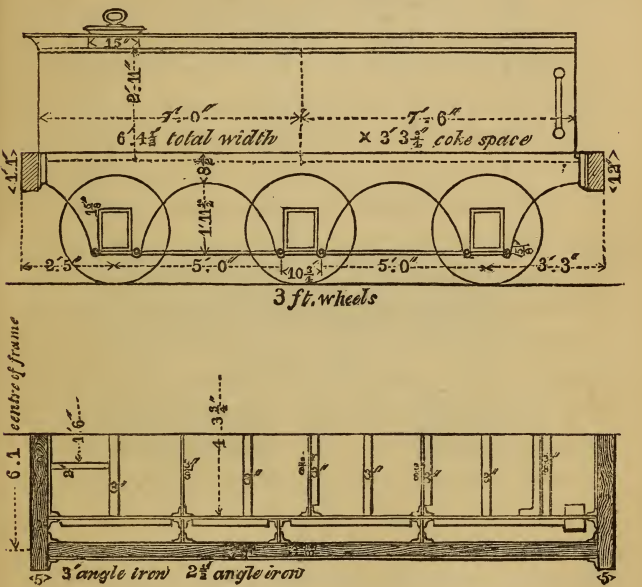
the water is simply injected by the velocity it acquires by the steam and atmospheric pressure. A valve is fitted to the under side so as to prevent the water in boiler flowing out when the apparatus is not working; and a cock must be fitted on the steam branch from boiler. The suction-pipes should be properly guarded in the tanks, with a suitable rose, having very small holes, as the smallest hard

substance would be forced along, and lodge in the nozzle, thus completely destroying the action of the instrument. We have known an instance, on taking a distant journey in a steam carriage for common roads, in which the injector would not work; the cover and spindle were taken out, and a small pebble was observed choking up the nozzle, which was extracted with a piece of wood having a small quantity of tallow on the end; thus the stone adhered to the tallow, and the journey was resumed, at least so far as we could, for we found the injector would not throw the water when the machine was in motion, which was attributed to the jolting going over the rough macadamised roads. However, it works admirably for locomotives, although there seemed to be grave doubts about its economy over that of a good-constructed steam-pump; for the steam-pump throws hotter water, and all the exhaust steam can be utilised in the tender. For short lines, having frequent stoppages, the usual feed-pumps can be dispensed with, and a steam-pump substituted.

THE TENDER.

In dealing with the tender I will simply give drawings. The size of the tank and capacity for coal must be regulated by the distance of the line of railway The lighter the tender is, the duty performed with the engine will be greater, for the tender just adds weight to the train. The structure must

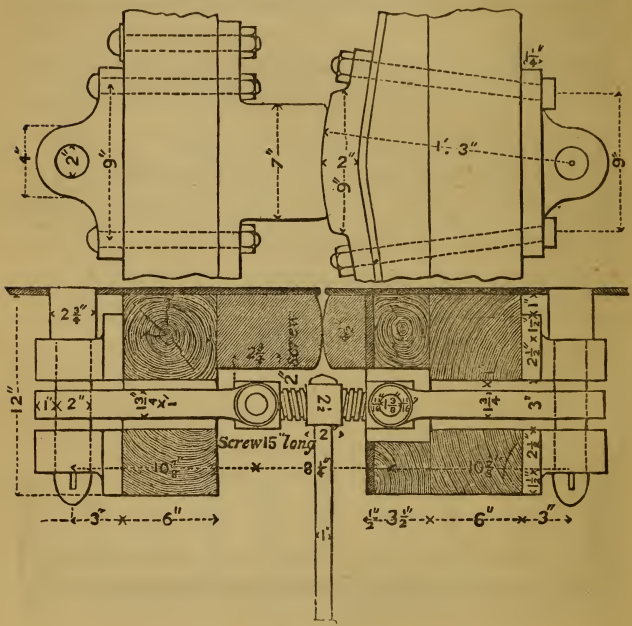
be simply strong and substantial, and the requisite brake gear of the simplest and best construction—two parallel bars, moving forward and backward, with the necessary willow blocks attached thereto, with suitable wrought-iron brackets, the bars being



Tender.

guided in three places, having a rack on each, worked by a pinion, with lever, the spindle carrying the lever and pinion; on the end of the lever there is a jaw, having an oscillating nut, with screwed rod and handle passing up to the top of tank, to

which it is fitted with a suitable bracket. The tender is connected to the engine with a right-and-left-hand screwed coupling: in some instances a plain drag-link is substituted. In case of the drag-



Coupling between Engine and Tender.

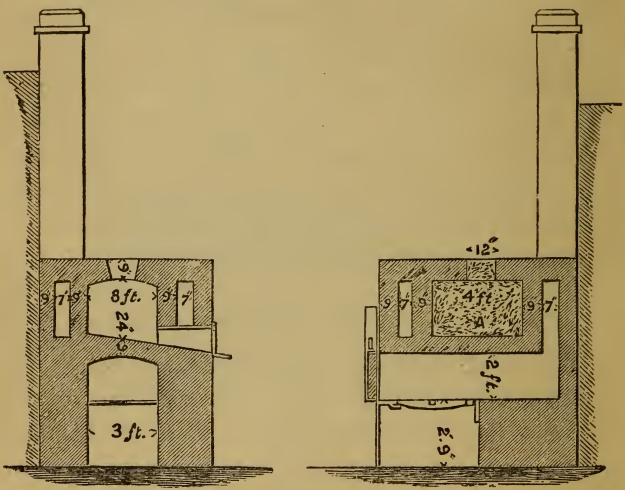
link giving way, two safety chains are attached to the engine and tender beams; the back or draw-beam of the tender has a drag-shackle at the centre of beam, to which is attached a right-and-left screw, for drawing up the carriages and tender together,

having suitable safety chains in case of accident. The tender-beam has likewise similar buffing springs as on the front beam of engine. For short lines of railway the water-tank should form part of the engine : there are a variety of arrangements—some place a saddle tank over the body of the boiler. This plan is best suited for inside cylinder arrangements, while outside cylinders have the tank under the boiler, the framing for engine forming the sides of tank, connected with suitable pipes, while others place the tank at the back of engine. However, the best arrangement is certainly underneath the boiler; thus the weight is lower down, and the engine will run easier, and the weight so placed is utilised so as to give more adhesion or grip to the wheels.

KINDLING FURNACE AND SAND ROASTER.

When the rails are in a greasy condition, it is necessary to sprinkle them with sand, so as to increase the bite of the wheels; without this, in many instances, the wheels would simply revolve without imparting any motion to the train. The sand must be thoroughly dried, and it is even found necessary to roast it, thus producing a hard gritty powder. The best plan for doing so is by baking it in a fire-brick oven, and in all well-regulated railway locomotive workshops a furnace is always kept burning, named the kindling furnace, so that at any moment the stokers can get a shovelful of live

coal to kindle up the fire in the locomotive fire-box. The sand used to be roasted on a girdle of cast iron, placed over the kindling fire; the frequent rupture and cracking of the cast iron gave a great deal of trouble, as the sand fell into the fire. To remedy the evil the author designed a roasting oven, made



Kindling Furnace and Sand Roaster.

entirely of fire-brick, the oven A being filled with moist sand; the flame and heated gases play on the bottom of the oven, and all round the sides, and then up the chimney. The door of the furnace is made of cast iron, lined with fire-brick, and fitted with a chain and balance, the chain passing over

suitable pulleys. As the whole of the brickwork gets intensely hot, it is necessary to bind the building with angle iron round the edges, secured with cast-iron girders, with bolts at top and bottom running across the brickwork.

AGRICULTURAL ENGINEERING.

This class of machinery is of the highest importance. To cheapen the labour of the agriculturist is a field but few have trodden; but that field is so vast, and the benefits are so great, that ere long we trust the old ploughshare will be considered a thing of the past. The chief difficulty seems to me to be, that this class of machinery is rather expensive in first cost; and, unless a farmer cultivated largely, he would prefer the old method, arguing that he must have his team of horses, so he may as well plough with them as keep them idle. I may say, were more companies formed, so as to furnish machines, ploughing the land for so much, according to the situation, farmers would require fewer horses, and in the ploughing season they would be fully occupied in conveying manure, so as to keep the multiple steam plough in full work. The engines are so constructed that most of the parts can be disconnected independently of the boiler. The windlass consists of a single sheave, 5 feet in diameter, round which the rope takes half a turn. The groove into which the rope passes

round is formed of a double series of small leaves, which clasp and hold the rope until it takes a straight line, when the clips freely open and liberate it. The small leaves are made of chilled cast iron; they are not liable to much wear, and can be easily replaced without disturbing the main parts of the sheave.

Mode of Working.—On the headland are placed the engine and windlass, and directly opposite to them is the anchor, which is self-moving, and between them is the plough, which is pulled forwards and backwards, one end of the plough being at work, and the other end raised out of the ground alternately: this is to avoid the necessity of turning at the headlands. There is provision on the plough for tightening or slackening the rope, so as to suit any irregularities in the field. The anchor is made to take the side strain by the disc-wheels cutting into the ground; and it is moved along the headland at pleasure by the motion of the 5-feet sheave, which is turned by the ploughing rope. As the plough goes away from the anchor, the sheave winds up a rope stretched along the headland, and keeps the anchor opposite its work. The porters are used to prevent the rope trailing on the ground.

The price of the apparatus, consisting of engine with self-moving gear and windlass; a self-moving anchor and grappling anchor; 800 yards best steel rope, headland ropes, 18 rope porters, and

snatch-block; 4-furrow plough, with scarifiers attached:—

10-horse set	. . . .	£780
12 do.	. . . .	825
14 do.	. . . .	875

THE TRACTION ENGINE.

Although this class of engine has not found much favour in this country, owing to the usual horse traffic not becoming familiarised with such a powerful rival—indeed, in going along our railways, we may see horses and cattle racing across a field in great terror, which state of things would not do in our cities, nor even in the country, having full-blooded animals continually passing and repassing—still, in many situations they are very handy in drawing heavy loads, and as such should be used in a hostile country for transporting the munitions of war, conveying the produce of those countries, or, as it were, a feeder to our great railway systems. The engine is fitted with an extra large boiler, having 37 tubes $2\frac{3}{4}$ inches diameter; fire-grate, 34 inches × 31 inches, and can burn either wood or coal; the cylinder is 10 inches in diameter, and is surrounded with a steam-jacket, the cylinder being placed in the smoke-box. The engine is arranged with a governor, reversing-link, tender, and water-tank under foot-plate, spur-wheel and pinion, with

pitch-chain, and safety-valves, open and locked up, firing tools, wrenches, &c. The driving-wheels are 5 feet 6 inches in diameter, fitted with brake for descending inclines. Such an engine will draw 10 tons up an incline of 1 in 6.

Price, £420.

PRICES OF ORDINARY PORTABLE ENGINES.

Fitted with Cylinder on top of Fire-box.

4	horse-power		£165
5	ditto		180
6	ditto		200
7	ditto		215
8	ditto		230
8	ditto	2 cylinders	250
10	ditto	1 cylinder	270
10	ditto	2 cylinders	290
12	ditto	ditto	335
14	ditto	ditto	375
16	ditto	ditto	415
18	ditto	ditto	455
20	ditto	ditto	495

Fitted with Cylinder in the Smoke-box.

4	horse-power		£170
5	ditto		185
6	ditto		205
7	ditto		220
8	ditto		235
8	ditto	2 cylinders	255
10	ditto	1 cylinder	275
10	ditto	2 cylinders	295
12	ditto	ditto	340
14	ditto	ditto	380
16	ditto	ditto	420
18	ditto	ditto	460
20	ditto	ditto	500

PRICES OF HIGH-PRESSURE HORIZONTAL ENGINES.

High-pressure steam engines, complete, with governors, starting-valves, feed-pump, fly-wheel,

with rim turned, Cornish boiler, with steam-chest, safety-valves, gauge-cocks, blow-off cocks, connecting-pipes, and every requisite to make them complete :—

4	horse-power	£120
6	ditto	160
8	ditto	200
10	ditto	240
12	ditto	280
14	ditto	320
16	ditto	360
20	ditto	440

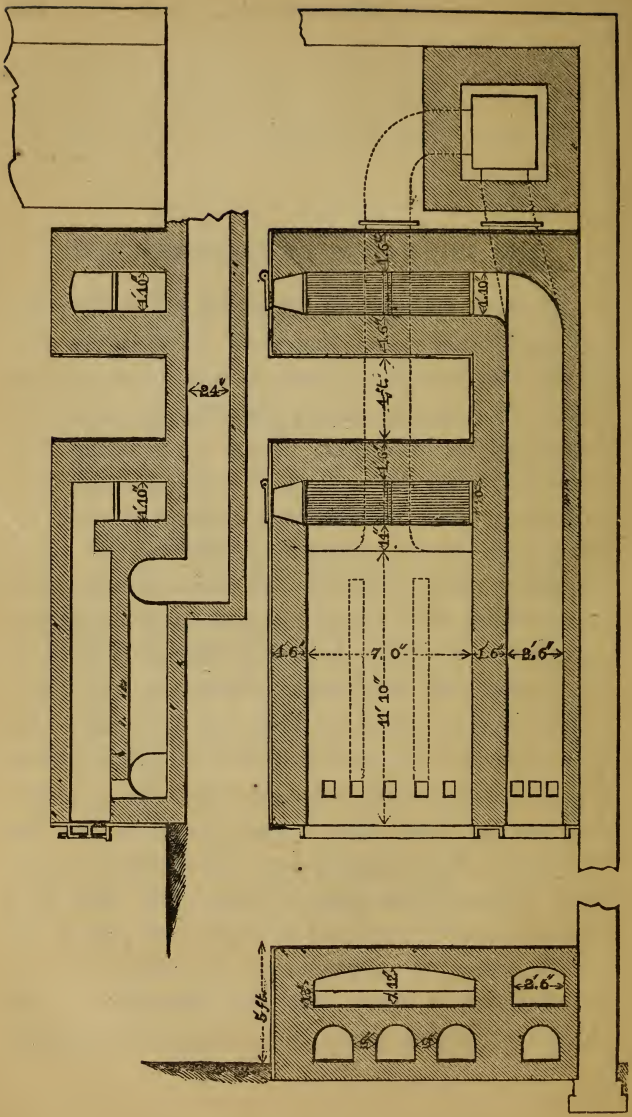
PRICES OF BOILERS IN THE NORTH.

	per cwt. s.	d.
Bulged or egg-ended	17	6
Flued	18	0
Double-flued, joining in one flue	19	6
Ditto with tubes at back	24	0
Ditto joining in two flues at back	20	6
Single-flued bulge-ended	21	6
Double-flued ditto	23	0
Locomotive fire-box, double-flued	26	0
Horizontal self-contained flue	28	0
Ditto self-contained tubular, with smoke-box	33	0
Deep fire-box locomotive boiler	40	0
Vertical tubular	45	0
Vertical inside dome boiler	30	0
Vertical double inside ditto	35	0

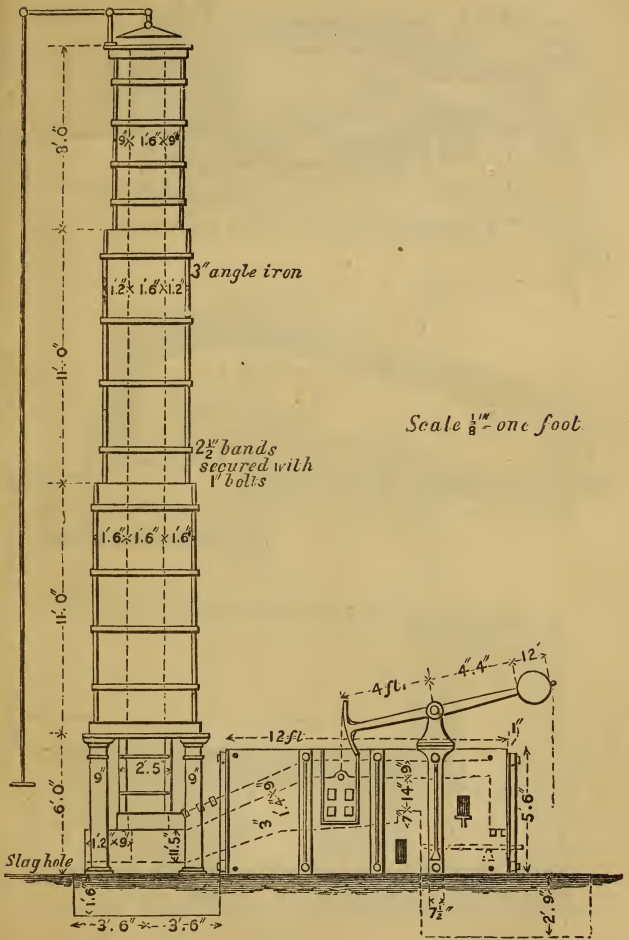
All the boilers are round, and preferred to have the ends made of Lowmoor or Bowling iron, as in egg-ended or bulged, and flanged in all parts, instead of angle iron. The extra cost is 2s. 6d. per cwt.

AIR FURNACES IN GENERAL USE.

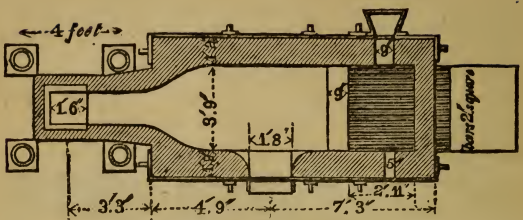
All these furnaces are lined with fire-bricks; and as they become very hot, it is necessary to bind them with cast-iron plates, having bolts running across the building, thus preventing the expansion cracking the brickwork. They are provided with cast-iron frame doors, lined with fire-bricks, having a lever and back balance, with chain to lift them by. The waste heat is utilised in furnaces for steam hammers, passing under and around the steam boiler, thus raising steam for the hammer. It is the general practice to strew the bottom of furnace with sand to protect the brickwork. Dampers are introduced so as to damp the fire when necessary. All the furnaces in the workshop have simply a natural current of air passing through, except the "cupola" and smithy fires, the blower being a fan, the "injector" fan being the best. The action is somewhat different from what is termed the silent fan; instead of revolving in an air-tight case, part of the air is expended in producing an inward current, working, as it were, like the blast-pipe in the locomotive engine, thus producing a powerful suction.



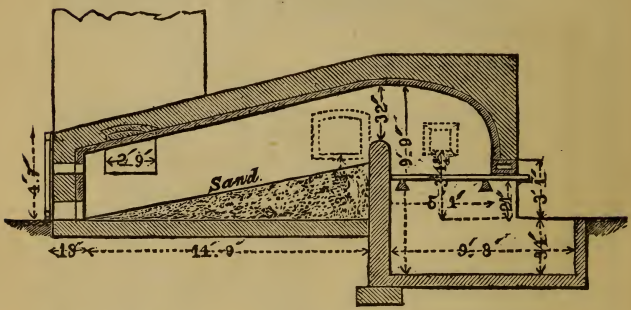
Plate, Wheel, and Angle-iron Furnace.

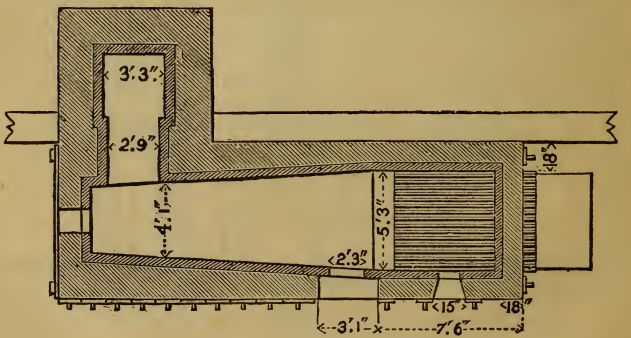


Air Furnace for Steam Hammer of 30 Cwt.

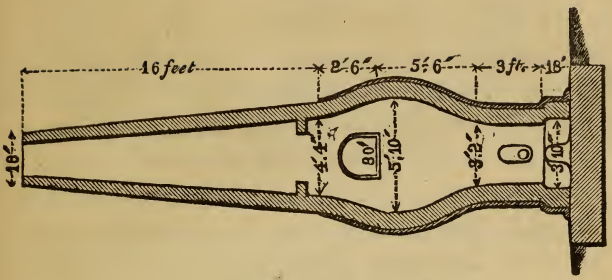


Plan of Air Furnace for Steam Hammer.

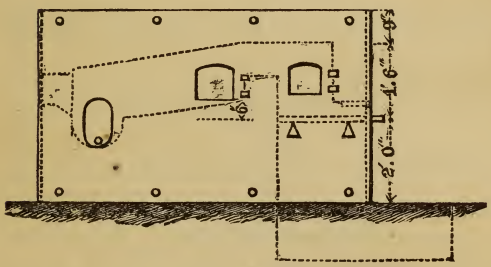


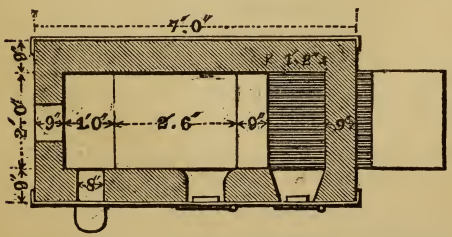


Air Furnace for Cast Iron.



Cupola for Cast Iron.





Air Furnace for Melting Scrap Brass.

TOOLS.

To give all the various special tools that are used in the workshop would fill a volume in itself. A great deal of ingenuity has been displayed in making them self-acting, so as to require but little attention on the part of the attendant; what had to be lined off, chipped, and filed, is now done entirely in the machine; and when details are properly designed, very little hand-labour is requisite.

THE END.

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